Performance Appraisal of Equipments in Opencast Mines

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

BY

PRADEEP KUMAR

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Department of Mining Engineering

National Institute of Technology

Rourkela

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Under the Guidance of

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CERTIFICATE

This is to certify that the thesis entitled, "***Performance Appraisal of Equipments in Opencast Mines***" submitted by **Mr. PRADEEP KUMAR**, **109MN0113**, in partial fulfillment of the requirement for the award of Bachelor of Technology Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under our supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

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An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others. I acknowledge my obligation to all of them.

And I offer my sincere thanks to the manager of Belpagad Opencast project, Sameleswari project and to all my friends who have patiently extended all sorts of help for accomplishing this undertaking.

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ABSTRACT

Mining is a very capital-intensive industry, and it is well known fact that the equipment availability and precise estimation of this utilization are very important since mine managers want to utilize their equipment as effectively as possible to get an early return on their investments as well reducing total production cost. While a lot of thrust is put on the selection of mining equipments not much consideration is paid towards the measurement of effectiveness of those equipments. The increase in automation, compounded by the increase in the size and capacity of equipment over the years has drastically changed the consequences of equipment ineffectiveness. In the present economic conditions, severe global competition, challenges of environmental and safety considerations, in order to achieve high production and productivity of HEMMs in opencast mines, it is pertinent to have high % availability and % utilization of equipments besides ensure overall equipment effectiveness vis-à-vis established CMPDI norms/global bench marks. This necessitates performance appraisal of various equipments in highly mechanized OCPs, critically analyze the idle/down time of equipments and take ameliorative measures to improve machine productivity and performance. OEE is a hierarchy of matrices which evaluate and indicates how effectively a production operation is utilized

The project work was carried out with the following objectives:

- To estimate % availability, % utilization and analyze idle hours of Dragline (10/70) at Belpahar OCP and Sameleswari OCP.
- To determine Overall Equipment Effectiveness (OEE) of Dragline and Surface Miner at BOCP and SOCP.

In this project, the performances of equipments from Samaleswari and Belpahar mines of MCL were evaluated.

Based on the field studies and analysis of data of Availability and Utilization of Draglines and Surface Miner at Belpahar and Sameleswari OCP the following conclusions are made:

- For Belpahar OCP, the average% availability and % utilization of Dragline (10/70) were found to be 80.71% and 66.79% respectively.
- For Sameleswari OCP the average % availability and % utilization of Dragline (10/70) were found to be 78.72% and 69.03% respectively.

- For Belpahar OCP, OEE of Dragline (10/70) was found to be 50%. For Sameleswari OCP, OEE of dragline (10/70) was found to be 38%. Hence OEE of Dragline (10/70) at BOCP was found be better than at SOCP.
- For Belpahar OCP, OEE of Surface Miner Wirtgen-2200 was found to be 55%. For Samleswari OCP, OEE of Surface Miner Wirtgen-2200 was found to be 43%. Hence the OEE of Surface Miner Wirtgen-2200 at BOCP was found be better than that at SOCP.

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INTRODUCTION

INTRODUCTION

Mining is a very capital-intensive industry, and it is well known fact that the equipment availability and precise estimation of this utilization are very important since mine managers want to utilize their equipment as effectively as possible to get an early return on their investments as well reducing total production cost. While a lot of thrust is put on the selection of mining equipments not much consideration is paid towards the measurement of effectiveness of those equipments. The increase in automation, compounded by the increase in the size and capacity of equipment over the years has drastically changed the consequences of equipment ineffectiveness. In the present economic conditions, severe global competition, challenges of environmental and safety considerations, in order to achieve high production and productivity of HEMMs in opencast mines, it is pertinent to have high % availability and % utilization of equipments besides ensure overall equipment effectiveness vis-à-vis established CMPDI norms/global bench marks. This necessitates performance appraisal of various equipments in highly mechanized OCPs, critically analyze the idle/down time of equipments and take ameliorative measures to improve machine productivity and performance.

OEE is a hierarchy of matrices which evaluate and indicates how effectively a production operation is utilized .Utilization of equipments can be only improved and controlled successfully by if an appropriate performance measurement system is used. One should plan to identify unproductive time losses within the system as these time losses affect availability, performance and quality. The consequence of proper data collecting system to estimate equipment effectiveness is also emphasized.

The use of large draglines for stripping overburden blocks in opencast coal mines is growing steadily in India with mines having stripping ratio up to 1:4 or 1:5 being successfully mined by this equipment. The main application of walking dragline exists in opencast coal projects where the volume of OB to be handled is many times greater than the volume of coal. Looking into the merits and huge scope of applications of draglines and the large capital investment in procuring, operating and maintaining the equipment it becomes essential to assess the performance of this equipment.

Surface miners made their debut in Indian surface mining industry in 1996. Presently, around 105 surface miners are working in Indian coal and limestone mines. The surface miners are being deployed largely on trial and error basis and the investors are interested in field experimental runs. Manufacturers evaluated the applicability of surface miners based on compressive strength of rock. In this context, it is logical to found a method to evaluate the performance of surface miners. The overall equipment effectiveness (OEE) of the surface miners has been determined to evaluate their performance.

In this project, an attempt has been made to analyze the performance of draglines and surface miners at two highly mechanized OCPs of Mahanadi Coalfields Limited (MCL).

1.1 OBJECTIVES

- To estimate % availability, % utilization and analyze idle hours of Dragline (10/70) at Belpahar OCP and Sameleswari OCP.
- To determine Overall Equipment Effectiveness (OEE) of Dragline and Surface Miner at BOCP and SOCP.

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 PRESENT STATUS OF DRAGLINE

Today, draglines are extensively used in strip mining of coal throughout the world. However, it has found wide range use in non-coal sector also, which includes surface mining of bauxite, phosphor, oil shale and tax sands. In the USSR, draglines are deployed widely for rehandling and sticking of 0/B spoil dumped by rail transport system. Occasionally, but rarely, these machines are used for loading into dumpers or bunkers as well for which special arch less buckets are available. In underwater digging such as for collecting sand and gravel, draglines are quite equipped with perforated buckets.

Presently there are five major manufacturers of draglines. They are Bucyrus Erie (US), Page (US), Marion (US), Rapier and Ransom (UK) and the Soviets. In India, Heavy Engineering Corporation is progressively manufacturing W-2000 model walking dragline indigenously in collaboration with Rapier and Ransom. Draglines used in open-cast mining typically range in size from machines equipped with 5 cubic meter drag buckets on 35 meter booms to the Bucyrus – Erie model 4250W, which is equipped with a 168 cubic meter drag-bucket on a 94.5 m boom. The longest boom length (121.9 m) dragline is offered by Bucyrus Erie, page, as well as, Marion. The largest boom from Ransom and Rapier is 105.5 m. The Soviets commissioned a long boom dragline with 120 m length during 1989. Works are now in progress to construct draglines having bucket capacity is high as 200 cubic meters. The current trend is to have machines with high bucket capacity and with short boom length. Apart from enhancing productivity and flexibility this arrangement can, most certainly, lend a degree of safety to the overall working conditions.

Most mines depend on the dragline 24 hours a day, 7 days a week. In many coal mines, it is the only primary stripping tool and the mine's output is totally dependent on the dragline’s performance. For these reasons, dragline design requires emphasis placed on developing component’s with high levels of reliability and predictability so that repairs and replacement of components can be scheduled at times that will least affect the overall mining operation.

Another critical designed consideration is that most repairs must be performed away from shop facilities. Although the dragline is a mobile piece of equipment, its enormous size prevents bringing to the shops for maintenance and repairs as s common with trucks and o her mine equipment. The designer must ensure that components are really accessible and that portable tools and rigging equipment are available for any contingency.

2.2 CONDITIONS FOR OPERATION OF DRAGLINE

- Gradients flatter than 1 in 6
- Seams should be free of faults & other geological disturbances
- Deposits with Major Strike length
- Thick seams with more than 25m thick are not suitable
- A hilly property is not suitable

2.3 CLASSIFICATION OF DRAGLINES

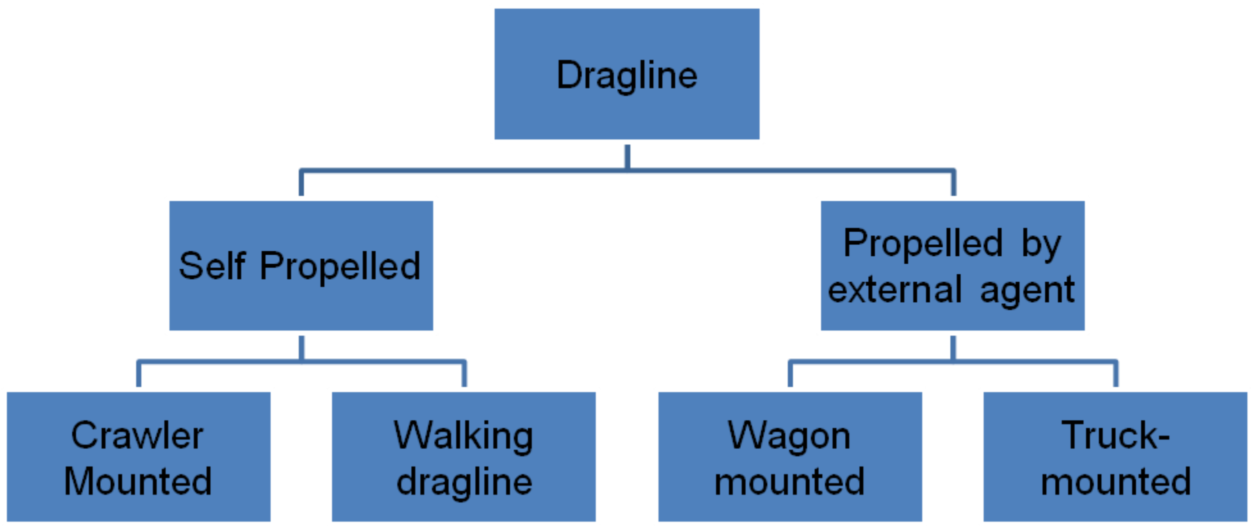


Fig. 2.1: Classification of Draglines

2.4 SYSTEM OF WORKING

In usual cycle of excavation, the bucket is situated above the material to be excavated. The bucket is then hand down and the dragrope is then drawn so that the bucket is pulled along the surface of the material. The bucket is lifted by using the hoist rope. A swing operation is then accomplished to move the bucket to the place where the material is to be dumped. The dragrope is then released causing the bucket to tilt and unfilled. This is called a dump operation.

The bucket can also be 'thrown' by winding up to the jib and then releasing a clutch on the drag cable. This would then swing the bucket like a pendulum. Once the bucket had passed the vertical, the hoist cable would be released thus throwing the bucket. On smaller draglines, a skilled operator could make the bucket land about one-half the length of the jib further away than if it had just been dropped. On bigger draglines, only a few extra meters may be extended.

Draglines have different cutting orders. The first is the side cast method using offset benches; this encompasses throwing the overburden sideways onto blasted material to make a bench. The second is a key pass. This pass cuts a key at the toe of the new highwall and also shifts the bench next towards the low-wall. This may also want a chop pass if the wall is blocky. A chop pass includes the bucket being dropped down onto an angled highwall to gauge the surface. The next sequence is the slowest operation, the blocks pass. However, this pass moves most of the material. It involves using the key to access to bottom of the material to lift it up to spoil or to an eminent bench level. The final cut if required is a pull back, pulling material back further to the low-wall side.

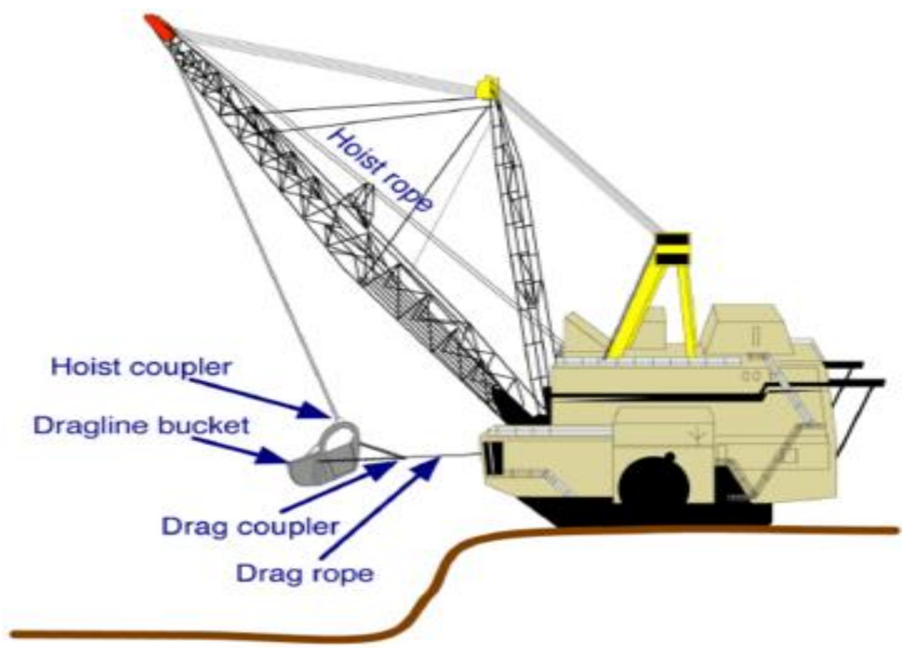


Fig. 2.2: Line Diagram of Dragline

2.5 THE OPERATING CYCLE OF THE DRAGLINE

It consists of five basic steps

- The empty bucket is positioned, ready to be filled.
- The bucket is dragged toward the dragline to fill it.
- The filled bucket is concurrently hoisted and swung over to the spoil pile. If the swing motion must be slowed to permit hoisting, the dragline is said to be hoist critical. When hoisting to the dump position is finished before the boom is in position to dump, the dragline is said to be swing critical.
- The material is dumped on the spoil.
- The bucket is swung back to the cut while concurrently being lowered and retrieved to the digging position.

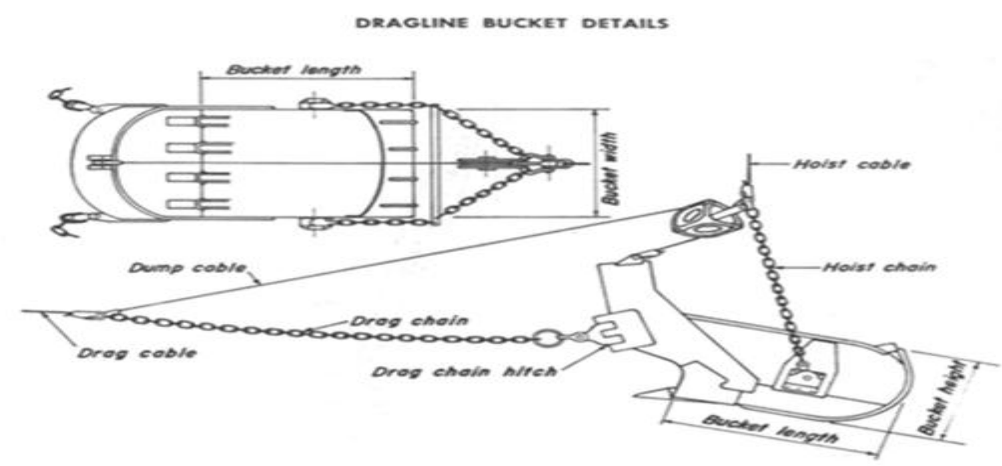


Fig. 2.3: Dragline bucket details

2.6 DRAGLINE – METHODS OF WORKING

- Simple side casting method
- Extended bench method
- Pull-back method

2.6.1 SIMPLE SIDECASTING METHOD

This is the simplest form of strip mining, which involves excavation of the overburden in a series of parallel strips. The strips are worked in a series of blocks. The 0/B from each strip is dumped into the void left by the previous strip after the coal mineral has been mined. It is customary to start the excavation of each block by digging a wedge shaped key cut with the dragline standing in line with the new high wall. From this position, the machine can most easily dig a neat and competent high wall. The nearest high wall is affected by starting the out with the dragline in line with the crest and moving it as the out gets deeper, ending with the machine in line with the toe of the new high wall. By this means, the slope angle of the new high wall can be closely con rolled. The width of each strip is usually designed so that the material from the key cut can be thrown into the previous cut without the need for rehandle.

Fig. 2.4: Dragline (10/70) of Sameleswari OCP

When the key cut has been completed, the dragline is moved close to the old high wall edge from where it can excavated the reminder of the blocks. With a suitable selection of bench height and block width, as well as, proper reach, casting can be done dear off the coal bench.

However, more often than not, the spoil pile touches the crest of the coal seam for obvious advantages mentioned early. Associated demerits are also present. Rehandling is no intended as it jeopardizes the economy of operations. Advance benching with this method is also practiced due o reasons already mentioned.

The manner in which a dragline must be applied to dispose of the material is of greater significance in affecting dragline productivity. In the simple case shown in the Fig. the dragline sets on the top of the material to be excavated and swings through an arc of between 45 to 90 degrees to dump the material. A typical average cycle time for the operation is 45 seconds. To obtain maximum reach, it is necessary to work the machine as close as possible to the high wall crest. In addition to the obvious risks to very expensive equipment, this practice reduces the degree of blasting which can be employed. In order to preserve a satisfactory edge from which to work, several mines 'buffer shoot' two or three strips ahead of the dragline. Buffer shooting is undoubtedly less efficient than shooting to a free face and no advantage can be taken of the material cast by the shot.

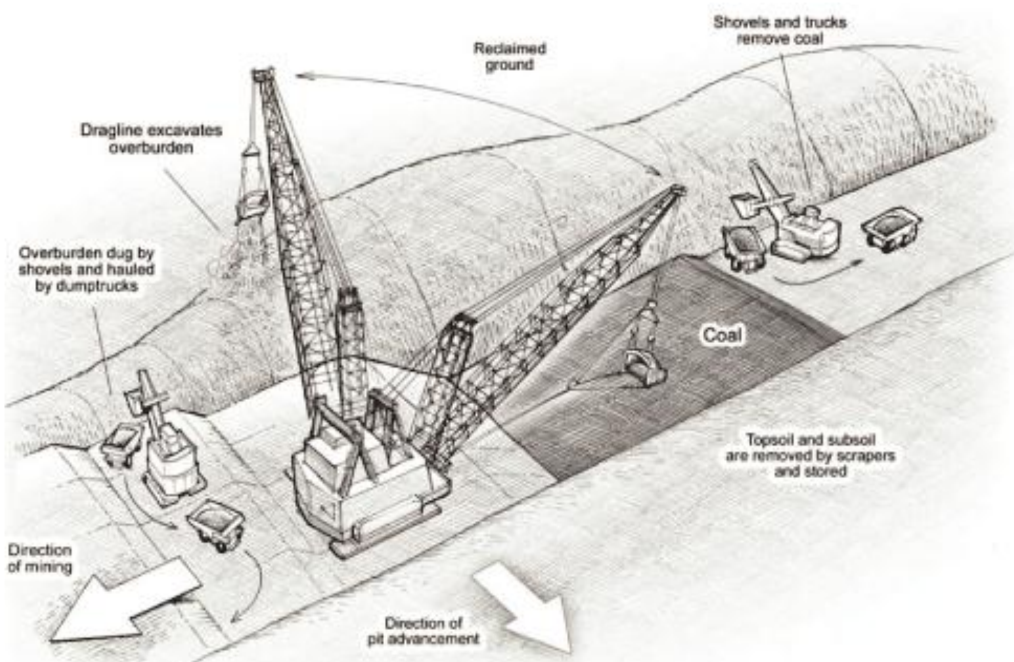


Fig. 2.5: Simple Sidecasting Method

2.6.2 DRAGLINE EXTENDED BENCH METHOD

Where overburden depth or the panel width exceeds the limit at which the dragline can sidecast the burden from the coal, a bridge of burden can be formed between the bank and the spoil which effectively extends the reach of the dragline. The bridge extends the bench on which the dragline is operating. The bridge is formed by material falling down the spoil bank or by direct placement with the dragline. To remove the bridge material from the top of coal, it must be rehandled.

Extended bench systems are adaptable to many configurations of pit geometry. In this method the dragline forms its working bench by chopping material from above the bench and forming the bridge, then moving onto the bridge to remove it from top of coal. The primary dragline strips overburden and spoils it into the previously excavated panel. This material is leveled, either by tractor-dozers or the secondary dragline, to form the bench for the secondary dragline. The secondary dragline first strips material near the highwall, then moves on to the bridge to move the rehandle material. In a two-dragline system, one machine must operate at the pace set by the other. Therefore, mine design must consider their respective capacities when assigning respective digging depths. The primary dragline strips overburden to the top of the first seam. Coal is removed, then a small parting dozed into the pit and the second coal seam removed. The secondary dragline strips the large interburden to the third and final seam. Extended bench systems must be designed carefully in order to maximize the dragline(s) productivity and to minimize the amount of rehandle.

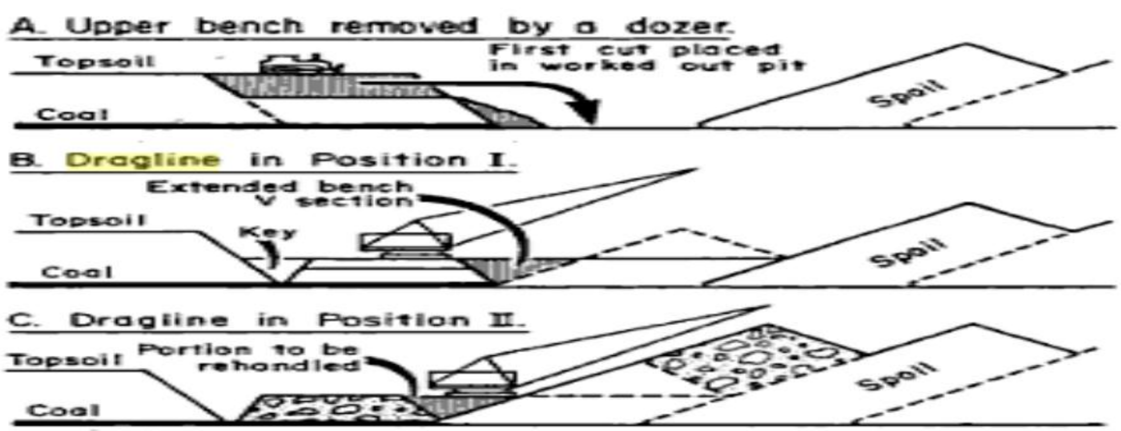


Fig. 2.6: Positions in extended bench method

2.6.3 DRAGLINE PULL-BACK METHOD

Occasionally, overburden to be stripped will be beyond the capacity of the dragline to spoil off the coal by any of the previous methods described. In this case, a secondary dragline can be placed on the spoil bank to pull back sufficient spoil to make room for complete removal of overburden.

Generally, rehandle volume is greater for the pull-back than an extended bench method of operation. However, it may also serve to level spoil piles in addition to providing more spoil area for the primary dragline. If the overburden/interburden is generally beyond the capability of draglines working on the highwall, the pullback method would seem to be a solution. However, great care must be given to the design of this method because of the inherent hazards of operations. Spoil slopes can be unstable, more so during periods of severe rainfall.

Draglines frequently are utilized to strip overburden from deeper coal seams than originally intended. Occasionally, spoil slopes cannot be maintained at designed angles. Various methods have evolved to stack more material into the spoil bank to alleviate these problems. The more common methods are described briefly:

1. Buck walls involve building the base of the spoil adjacent to the pit with competent material so that a steeper spoil slope near the base can be maintained.

2. Coal fenders require leaving a small wedge of coal untouched in the pit so that more spoil can be packed on the spoil slope.

3. Outside pit involves modifying the pit shape in order to develop the outside curve concept which increases the spoil area relative to the stripping area.

2.7 PRODUCTION CALCULATION

Based on the observed and recorded data in terms of average cycle time, A and U values the annual output (P1) of the dragline has been projected using formula

$P1 = (B/C)*A*U*S*F*M*N_s*N_h*N_d*3600$

Where

B is bucket capacity of the dragline in cubic meter.

C is the average total cycle time of dragline in second.

S is the swell factor.

F is the fill factor.

M is the machine travelling and positioning factor.

N_s is the number of operating shifts in a day.

N_h is the number of operating hours in a shift.

N_d is the number of operating days in a year.

In the above equation the values of average cycle time (C), A and U were substituted as per the recorded and acquired field observations. Remaining factors in the Eqn. (iii) (S, F, M, Ns, Nh, and Nd) were substituted as per the recommendations made by CMPDI in regard to the values of these factors in Indian coal mines.

2.8 DRAGLINES USED IN INDIA

2.8.1 Bharat Coking Coal Ltd. (BCCL)

Table 2.1: Draglines in Bharat coking coal Ltd. (BCCL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Block II	24x96	1	Mid seam of coking coal worked. OB dumped in coal bearing area to be removed later
2.	Joyrampur	5x45	1	--------------------
Total for BCCL			2	

2.8.2 Eastern Coalfields Ltd. (ECL)

Table 2.2: Draglines in Eastern Coalfields Ltd. (ECL)

	Project	Capacity of Dragline	No. of draglines	Geo-mining conditions
1.	Sonepur Bazari	26 cu m	1	Multi seam deposit, bottom dium thick seam exposed by gline
Total for ECL			1	

2.8.3 Northern Coalfields Ltd. (NCL)

Table 2.3: Draglines in Northern Coalfields Ltd. (NCL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Amlori	24x96	1	MOHER-SUB BASIN, SIngrauli Coalfield. The NCL is presently working in Moher sub-basin of Singrauli coalfield. The basin has three seams in most of its area. The upper seams are 8-10 m thick with a parting of about 40 m in between. The lowermost seam is 16-22 m thick and has a parting of about 40 m between it and the second seam. The seams are flat (about 2 degree gradient). Upper seams are worked by shovel dumper combination and draglines are used only for removal of OB above the bottom most seam. When all the three seams are worked in any project of this sub-basin, the percentage of OB handled by dragline will only be 20-25 % of the total OB
2.	Bina	10x70 - 2 24x96 - 2	4	
3.	Dudichua	24x96	2	
4.	Jayant	15x90 - 1 24x96 - 3	4	
5.	Khadia	20x90	2	
6.	Nigahi	20x90	2	
Total for NCL			15	

2.8.4 South Eastern Coalfields Ltd. (SECL)

Table 2.4: Draglines in South Eastern Coalfields Ltd. (SECL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Bisrampur	30 cu.m	2	Single thin seam at shallow depth
2.	Chirimiri	10x70	1	12-13 m thick seam developed by bord and pillar previously
3.	Dhanpuri	10x70 – 1 20x90 – 1	2	6-7 m thick seam
4.	Dola/Rajnagar	10x70	1	Two thick seams with thin parting in between

5.	Jamuna	5x45 – 1 10x70 – 1	2	Thin seam at shallow depth
6.	Kurasia	5x45 – 1 10x70 – 1 11.5 cu.m – 1	3	Multi seam working with thin partings in between
Total for SECL			11	

2.8.5 Western Coalfields Ltd. (WCL)

Table 2.5: Draglines in Western Coalfields Ltd. (WCL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Ghughus	24x96	1	Single thick seam (16 to 22 m) developed in two sections
2.	Sasti	20x90	1	Single thick seam (16-22 m)
3.	Umrer	4x45 – 1 7 cu.m – 1 15x90 – 1	3	Multi seam deposit, bottom seam is thickest. Shovel-dumper for upper seams. Small dragline used for rehandling
Total for WCL			5	

2.8.6 Singareni collieries Co. Ltd. (SCCL)

Table 2.6: Draglines in Singareni collieries Co. Ltd. (SCCL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Ramagundam OC-I	24x96	1	Upper seams exposed by shovel-dumper. Lower seams exposed by dragline
2.	Ramagundam OC-III	30 cu.m	1	Parting between two seams taken by dragline
Total for SCCL			2	

2.8.7 Mahanadi Coalfields Ltd. (MCL)

Table 2.7: Draglines in Mahanadi Coalfields Ltd. (MCL)

	Project	Capacity of Dragline	No. of Draglines	Geo-mining conditions
1.	Balanda	4x45 - 1 10x60 – 1 11.5 cum– 1 20x90 – 1	4	A thick seam (10-16 m) is split into 3 to 4 splits in part of the area. Mostly, single seam working
2.	Belpahar	10x70	1	Parting between two seams taken ragline
3.	Lajkura	10x70	1	OB above a thick seam interbanded seam taken by dragline
4.	Samaleshwari	10x70	1	---------------
Total for MCL			7	

2.9 SURFACE MINER

2.9.1 INTRODUCTION

Surface miner is a continuously operating mobile opencast machine. It cuts consolidated soils and semi –solid rocks without drilling and blasting the cut material is pre-crushed and suitable for belt conveying, loading, transporting and transferred to downstream means of transportation. Surface miners (SM) were initially developed in the mid- 1970s, and their use has gained popularity since the 1990s, with improved cutting drum design and higher engine power leading to more efficient machines. These improvements have enabled operators to excavate rock in a more eco-friendly and economical manner. For cost-effective rock excavation by SM, two basic elements have to be considered: the machine and the rockmass. The machine can be bespoke to costume precise requirements, but the rock-mass is obviously a natural component and thus immutable. Therefore, it is imperative to have good understanding of the characteristics of the rock to be excavated in order to select the most appropriate machine.

Various methods for evaluating the applicability of surface miners based on the rock properties have been developed in the past. The main aim of these evaluations was to reduce the need for on-site machine trials, which are expensive and time consuming although currently accepted as the most accurate and reliable method of assessment.

The evaluation methods that are most common in the literature focus mainly on the cutting aspects of the machines

The surface miner brings with it various advantages compared to the conventional mining methods

- Environmental friendly mining
- Minimal loss of mineral
- Better truck utilization while carrying crushed mineral
- Elimination of primary crushing
- Reduced cost of transportation
- Selective mining
- Reduced manpower

2.9.2 OPERATION

Surface Miner operates

- According to the Rock cutting technology
- The cutting drum is provided with point attack picks
- Which cut the mining face during the continuous
- Advance of the machine on crawler track assemblies.

2.9.3 GENERAL DATA FOR SURFACE MINER

Table 2.8 general data for Surface Miner

	Middle drum	**Front cutting boom**	**Front cutting wheel**
Cutting width drum [mm]	250-4200	5250	7100
Cutting depth/height [mm]	0-800	1000/5000	0-2900
Capacity	For all machines output is related to material characteristics		
Weight [t]	40-190	135	540
Installed power	450-1200	750	3340
Manufacture	Wirtgen/Bitelli/ Huran	Voest Alpin	Krup Fordertechnik

Fig. 2.7: Surface Miner of Sameleswari OCP

2.9.4 FACTORS AFFECTING PRODUCTIVITY OF SURFACE MINER

As per Cuttability index, productivity of surface miner mainly can be pretentious by following ways-

Point load index

It is an index to determine strength of hard rock materials. It is influenced by sample size.

Volumetric joint count

It is defined as the sum of the number of joints per meter for each set present, and is measured along the joint set perpendicular.

Abrasivity

If the abrasivity increases there will be decrease in performance of surface miner

Cuttability

Performance of surface miner depends on Cuttability index, as the Cuttability index increases performance of surface miner decreases. If Cuttability index exceeds greater than 80, surface miner should not be deployed.

Machine Configuration

Performance of surface miner depends on machine configuration such as cutting tool configuration, drum weight, drum width, engine power, and nature of coolant for tips.

2.9.5 ADVANTAGE OF SURFACE MINER OVER CONVENTIONAL SYSTEM OF MINING

Mining by surface miner	Conventional system of mining
No requirement of drilling, blasting and crushing	Requirement of drilling, blasting and crushing.
Mining is possible in close proximity of village, road and other permanent structure.	Mining is not possible due to restriction in blasting
No chance of spontaneous heating and fire.	Blasting produces crack in the coal bench which leads to spontaneous heating and fire.
Stability of bench and high wall is comparatively much better.	Stability of benches and high wall is comparatively poor due to induced stress caused by blasting.
It is an environmentally friendly method of mining	Drilling, blasting and crushing produces adverse effect on environment.
Selective mining is possible as a result quality of mined out coal is better.	Selective mining is not possible.
Thin seam mining is possible as a result non-workable seam becomes workable.	Thin seam mining is not possible.
Less capital investment and infrastructure is required.	High capital investment and infrastructure is required.
Top of bench and high wall is smooth	Top of bench and high wall is uneven.

2.9.6 Production calculation

Theoretically the quantity of mineral cut by surface miner can be estimated by the following formula

$Q= V_m*h*b*60m^3/h$

Where

Q= Quantity cut, m^3/h
V_m= Machine speed, m/h
H= Milling depth, m
B= Milling drum width, m

2.10 Evaluation of availability (A) and Utilization (U)

To evaluate A and U, field data was acquired and maintained on day to day basis on all the dragline under study. The collected data was substituted in equations (1) and (2) for the computation of A and U.

$$A=\frac{SSH-(BH+MH)}{SSH} \quad \ldots\ldots. \tag{1}$$

$$U=\frac{SSH-(BH+MH+ID)}{SSH} \quad \ldots\ldots.. \tag{2}$$

Where, SSH is scheduled shift hour,

MH is maintenance hour,

BH is breakdown hour and

ID is idle hour.

2.11 OVERALL EQUIPMENT EFFECTIVENESS

OEE is a simple tool that will help to measure the effectiveness of their equipment. It takes the most common and important sources of productivity loss, which are called six big losses and given in Table 2.9 These losses are quantified as availability, performance and quality in order to estimate OEE.

OEE = Availability × Performance × Quality

Table.2.9 Six Big Losses

Six Big Loss Category	OEE Loss Category	OEE Factor
Equipment Failure	Downtime Losses	Availability (A)
Setup and Adjustment		
Idling and Minor Stoppages	Speed Losses	Performance (P)
Reduced Speed		
Reduced Yield	Defect Losses	Quality(Q)
Quality Defects		

2.11.1 AVAILABILITY

Availability takes into account Down Time Loss, which includes any Events that stop planned production for an appreciable length of time (usually several minutes - long enough to log as a trackable Event). Examples include equipment failures, material shortages, and changeover time. Changeover time is included in OEE analysis, since it is a form of down time. While it may not be possible to eliminate changeover time, in most cases it can be reduced. The remaining available time is called Operating Time.

$$\text{Availability} = \frac{\text{Net Available Time} - \text{downtime losses}}{\text{Net Available Time}} \times 100$$

2.11.2 PERFORMANCE

Performance takes into account Speed Loss, which includes any factors that cause the process to operate at less than the maximum possible speed, when running. Examples include machine wear, substandard materials, misfeeds, and operator inefficiency. The remaining available time is called Net Operating Time.

$$\text{Performance} = \frac{\text{Operating Time} - \text{Speed Losses}}{\text{Operating Time}} \times 100$$

2.11.3 QUALITY

Quality takes into account Quality Loss, which accounts for produced pieces that do not meet quality standards, including pieces that require rework. The remaining time is called Fully Productive Time. Our goal is to maximize Fully Productive Time.

$$\text{Quality} = \frac{\text{Net Oprating Time} - \text{Defect Losses}}{\text{Net Operating Time}} \times 100$$

Table 2.10: Losses occurred during the equipment operation.

Sl. No.	Loss Classification	Description
1	Nonscheduled time	Time duration for which equipment no scheduled to operate.
2	Maintenance time	Maintenance time spent for periodic maintenance of Dragline
3	Unscheduled maintenance time	time spent for breakdown
4	Idle time	Equipment is ready but no not available of power, and cable shift, dozing, blasting drilling.
5	Quality	Loaded to its full capacity. That is equivalent to unqualified products and known as filling factor.

CHAPTER 3

DATA COLLECTION, ANALYSIS AND INTERPRETATION

3.1 METHODOLOGY

The methodology adopted in this project is as follows:

- In order to achieve the stated objectives, field survey and data collection was carried out in some of the large opencast coal project of Mahanadi Coalfields Limited (Belpahar OCP and Sameleswari OCP).

- A record of working hours (WH) idle hour (IH), maintenance hour (MH) and break down hour (BH) maintained by mines were collected for dragline and surface miner.
-
- Calculation of availability and utilization by:

$$A=\frac{SSH-(BW+MH)}{SSH}$$

$$U=\frac{SSH-(BH+MH+ID)}{SSH}$$

Where, SSH is scheduled shift hour, MH is maintenance hour, BH is breakdown hour and ID is idle hour.

- **Calculation of OEE** by:

  OEE = Availability × Performance × Quality

- Comparison of availability and utilization of by the graph.
- Analysis of idle hours

3.2 MONTHLY PERFORMANCE OF DRALINE (10/70) IN BELPAHAR OCP

Table 3.1: Performance of Dragline (10/70) at Belpahar OCP for 2010

Sl. No.	Sheduled Shift hrs.	Working hours	Breakdown hours	idle hours	Maintenance hours	%Availability	%Utilization
JANUARY	670	406	01	206	57	91	61
FEBRUARY	670	502	13	100	55	90	75
MARCH	630	497	12	44	77	86	79
APRIL	670	361.30	28.15	221	59.15	87	54
MAY	650	219.5	119	117	42.5	63	45
JUNE	670	385.15	14.30	228	42	92	58
JULY	650	367	1	239	43	93	56
AUGUST	670	464	32	141.5	32	90	69
SEPTEMBER	670	258	326	59	27	47	39
OCTOBER	650	446	46	68	90	79	69
NOVEMBER	670	471	68	81	50	82	70
DECEMBER	650	513	22	40	75	85	79

Table 3.2: Performance of Dragline (10/70) at Belpahar OCP for 2011

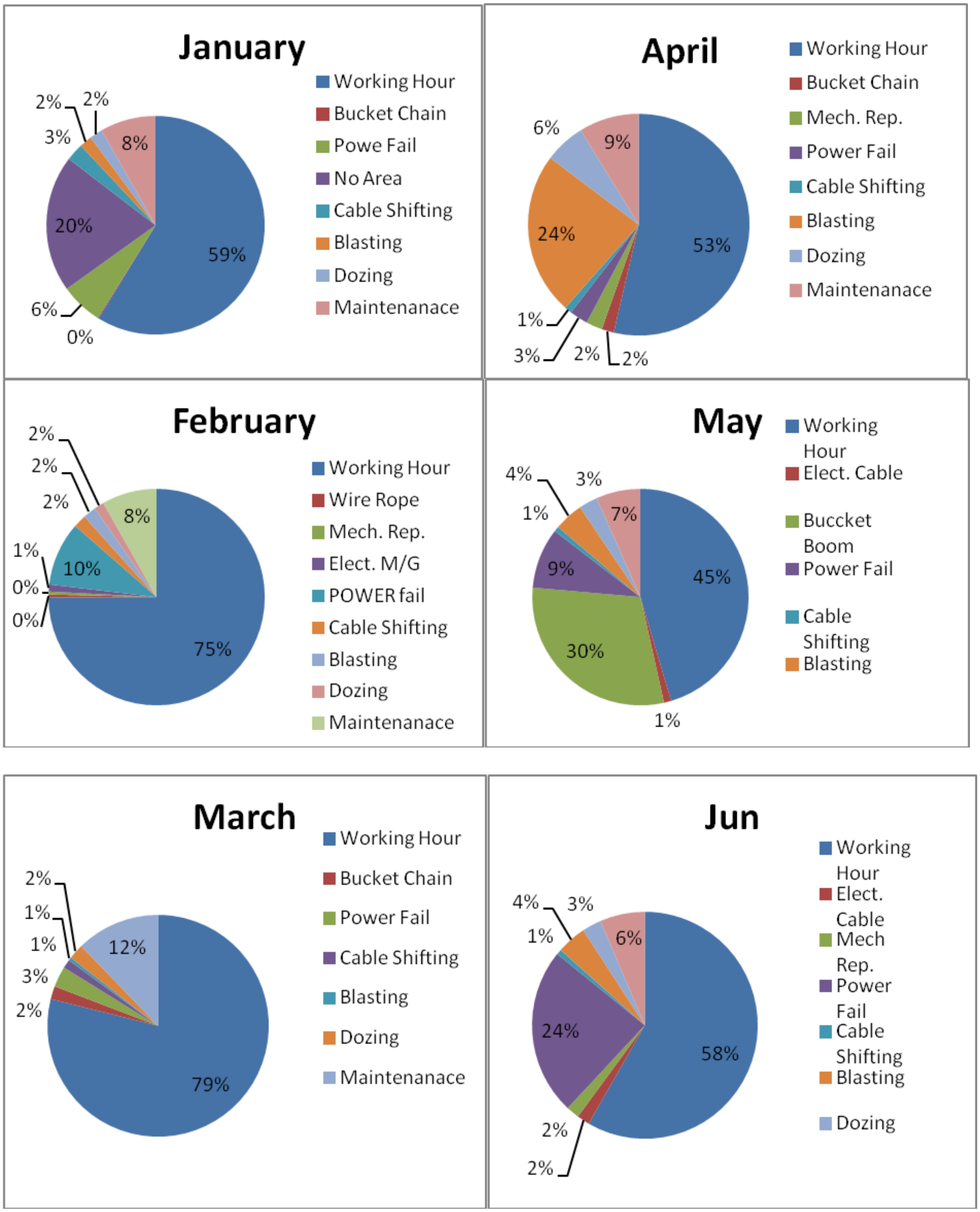
Sl. No.	**Sheduled Shift hrs.**	**Working hours**	**Breakdown hours**	**idle hours**	**Maintenance hours**	**%Availability**	**%Utilization**
JANUARY	670	408	5	185	72	88	61
FEBRUARY	670	535	18	67	50	90	80
MARCH	630	497	21	56	56	88	79
APRIL	670	404	126	85	55	73	60
MAY	650	191	395	43	21	36	29
JUNE	670	508	25	97	40	90	76
JULY	650	528	00	64	58	91	81
AUGUST	670	549	15	64	42	91	82
SEPTEMBER	670	442	00	49	179	73	66

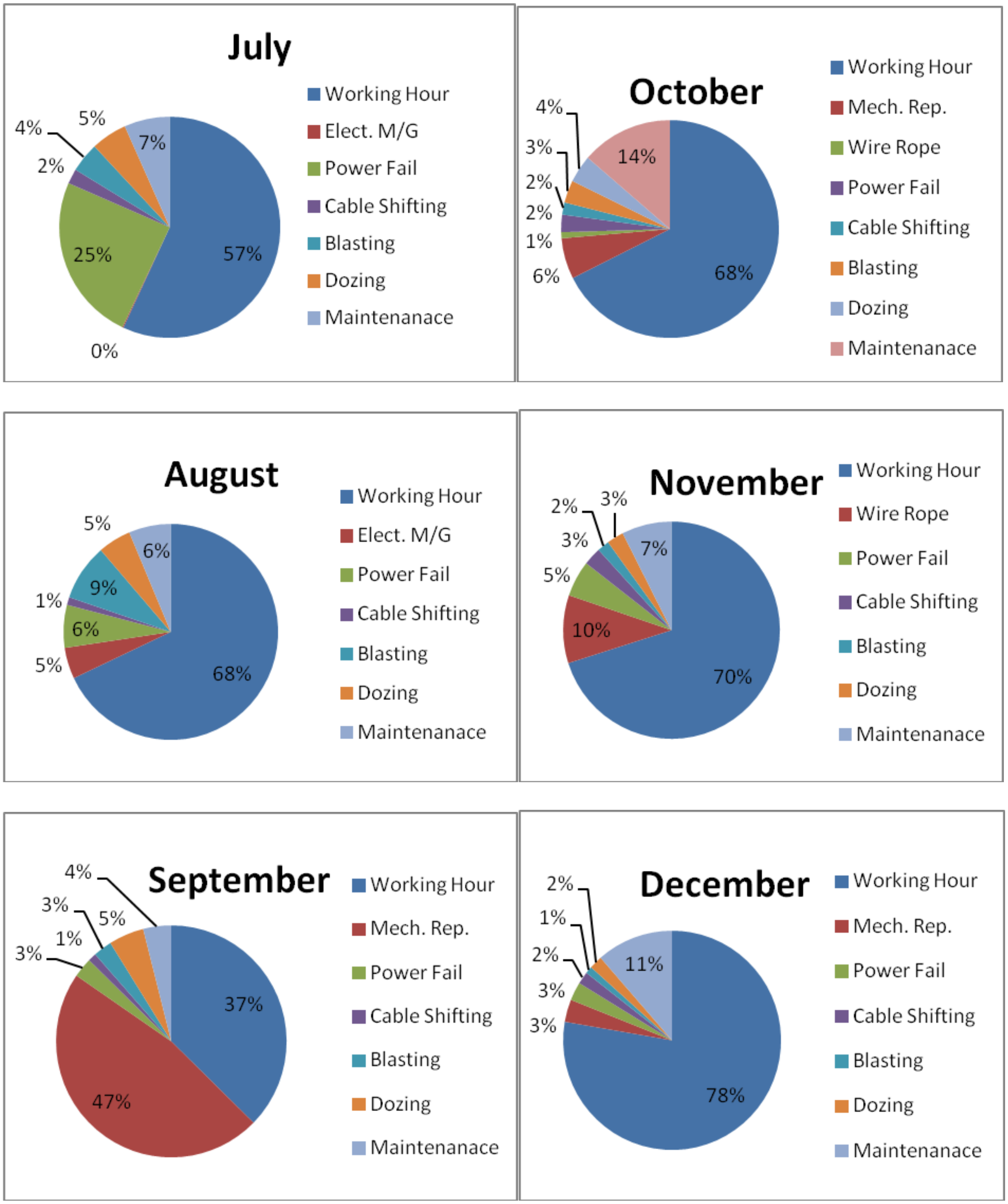
Table 3.3 performance of dragline (10/70) at Belpahar OCP for 2012

Sl. No.	**Sheduled Shift hrs.**	**Working hours**	**Breakdown hours**	**idle hours**	**Maintenance hours**	**%Availability**	**%Utilization**
JANUARY	670	569	5	45	51	91	85
FEBRUARY	670	573	2	30	65	90	86
MARCH	630	475	22	78	55	88	75
APRIL	670	529	25	33	83	84	79
MAY	650	509	18	35	88	84	78
JUNE	670	560	4	56	50	92	84
JULY	650	486	27	66	71	85	75
AUGUST	670	572	5	27	66	89	85
SEPTEMBER	670	566	18	8	78	86	84
OCTOBER	650	535	9	18	88	85	82
NOVEMBER	670	430	103	52	85	72	64
DECEMBER	650	469	89	41	51	78	72

3.2.1 Pie charts on monthly performance assessment of Dragline (10/70) at Belpahar OCP for the years 2010-12 have been presented in Figs. 3.1 to 3.3

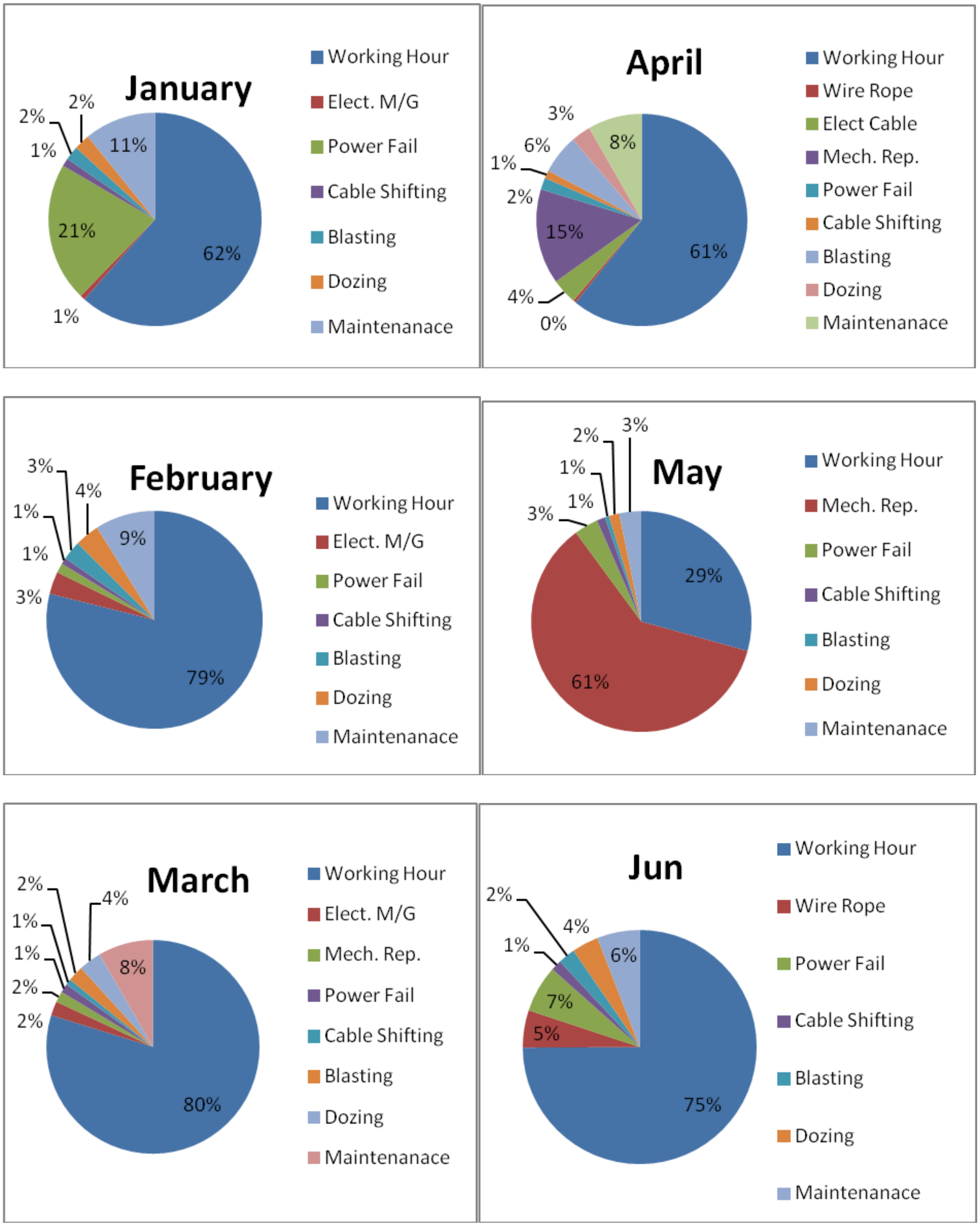
FOR 2010





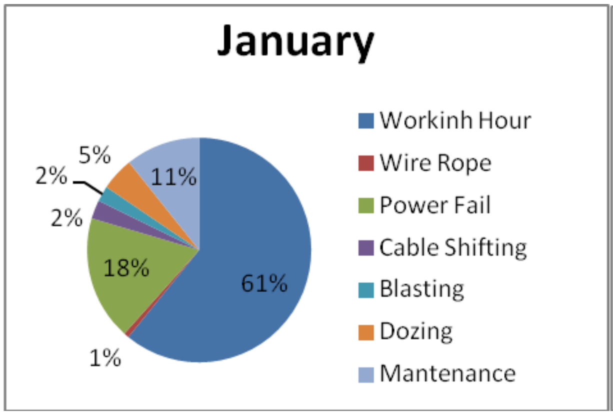
Figs. 3.1: Pie charts for Dragline at BOCP in 2010

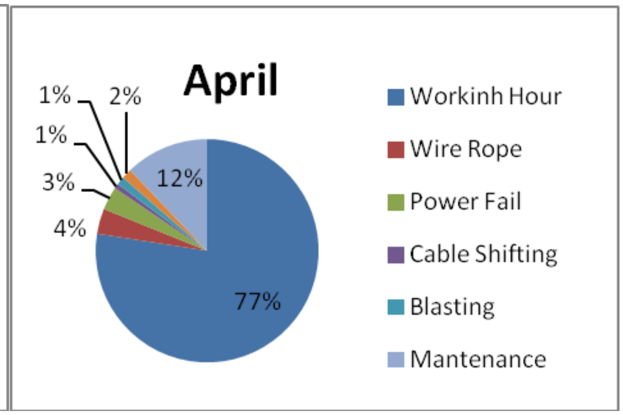
FOR 2011

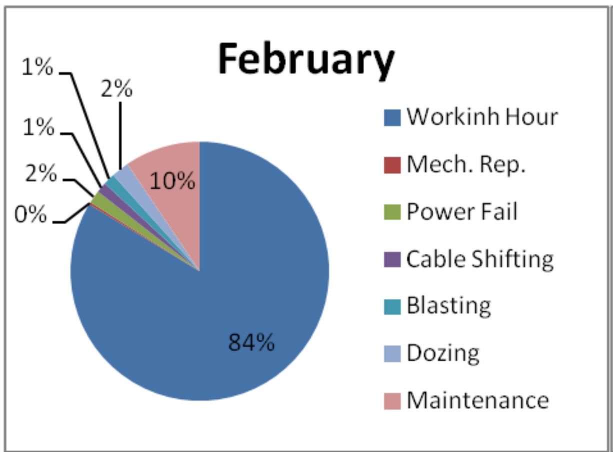


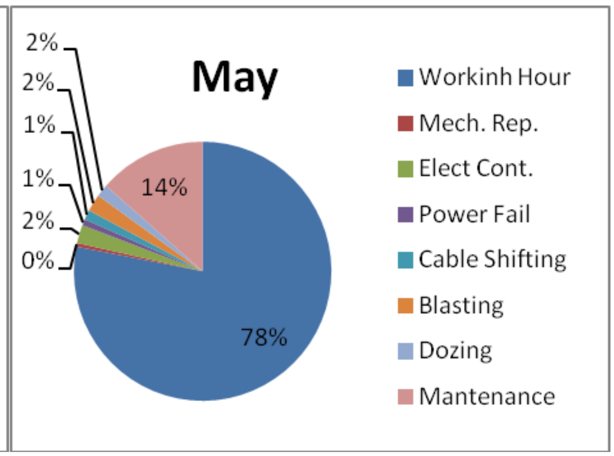
Figs. 3.2: Pie charts for Dragline at BOCP in 2011

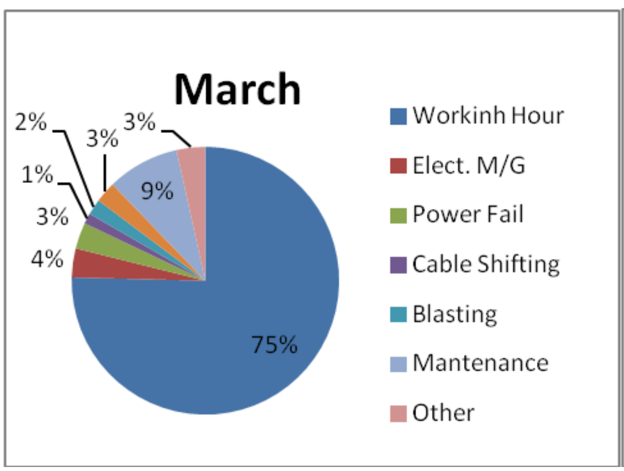
FOR 2012

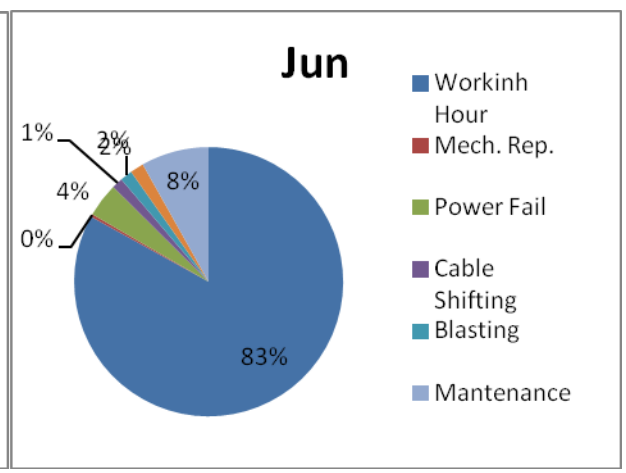

January
Workinh Hour
Wire Rope
Power Fail
Cable Shifting
Blasting
Dozing
Mantenance
61%
18%
11%
5%
2%
2%
1%

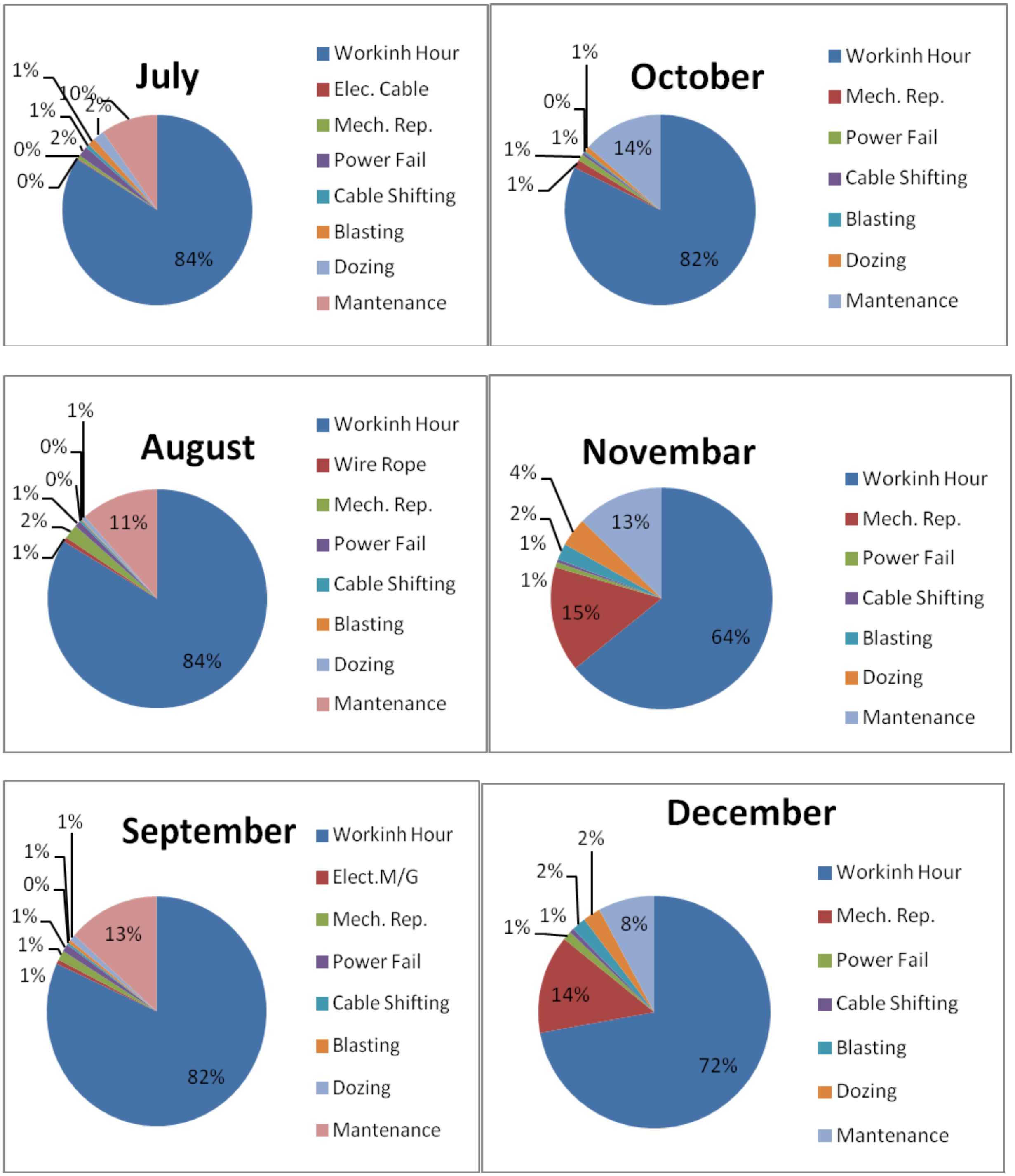

April
Workinh Hour
Wire Rope
Power Fail
Cable Shifting
Blasting
Mantenance
77%
12%
1%
2%
1%
3%
4%


February
Workinh Hour
Mech. Rep.
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance
84%
10%
1%
2%
1%
2%
0%


May
Workinh Hour
Mech. Rep.
Elect Cont.
Power Fail
Cable Shifting
Blasting
Dozing
Mantenance
78%
14%
2%
2%
1%
1%
2%
0%


March
Workinh Hour
Elect. M/G
Power Fail
Cable Shifting
Blasting
Mantenance
Other
75%
9%
2%
3%
3%
1%
3%
4%


Jun
Workinh Hour
Mech. Rep.
Power Fail
Cable Shifting
Blasting
Mantenance
83%
8%
1%
4%
0%



Figs. 3.3: Pie charts for Dragline (10/70) at BOCP in 2012

3.2.2 %AVAILABILITY AND %UTILIZATION GRAPH OF DRAGLINE (10/70) FOR BELPAHAR OCP

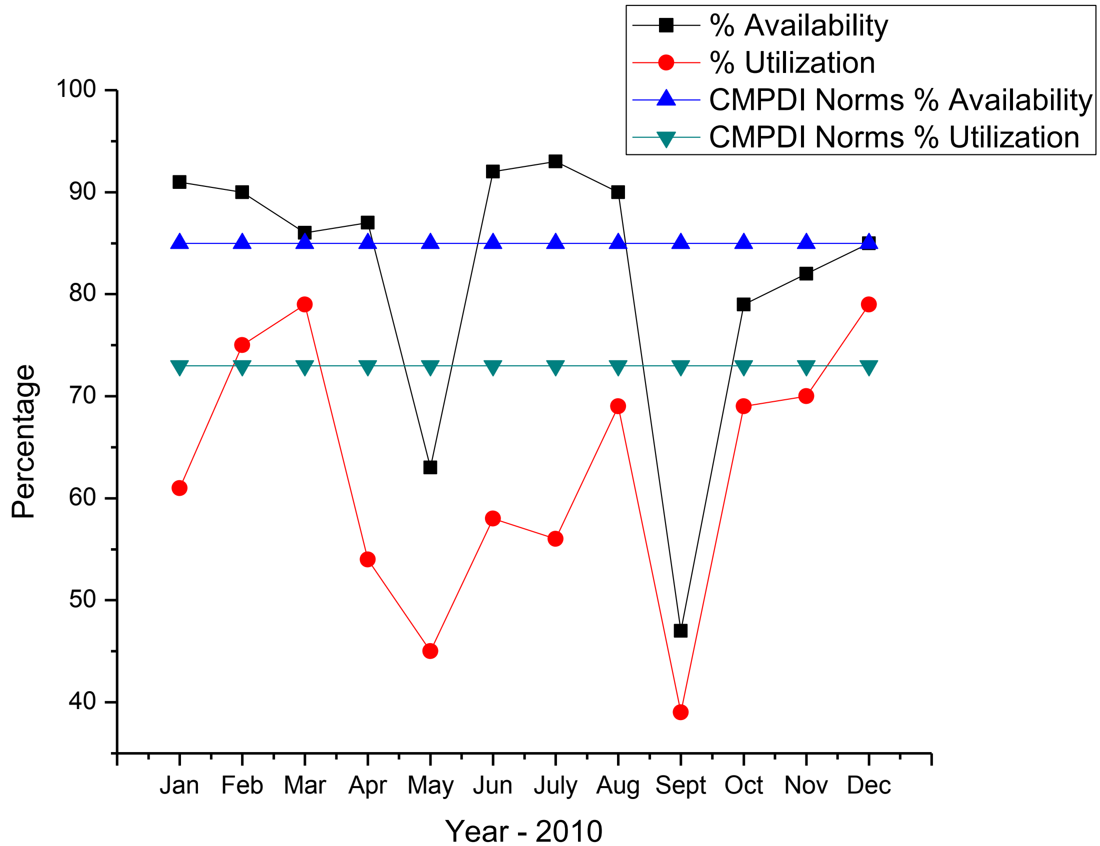


Fig. 3.4: Graph representing percentage Availability and Utilization of Dragline (10/70) for 2010

According to CMPDI norms %Availability and %Utilization of dragline (10/70) is 85% and 73%. As per fig. 3.4 % availability was below the CMPDI norms in the months May (63%) and Sept (47%) and marginally low in October and November because breakdown and maintenance hours was more in these months. % Utilization was less than the required CMPDI norms except in Feb, March, and Dec with the minimum utilization occurred in Sept (39%). This can be attributed to:

- Not properly benchmarking of mining operations/ equipment.
- Dozing operation
- Not sufficient loose blasted material
- No fully power supply available

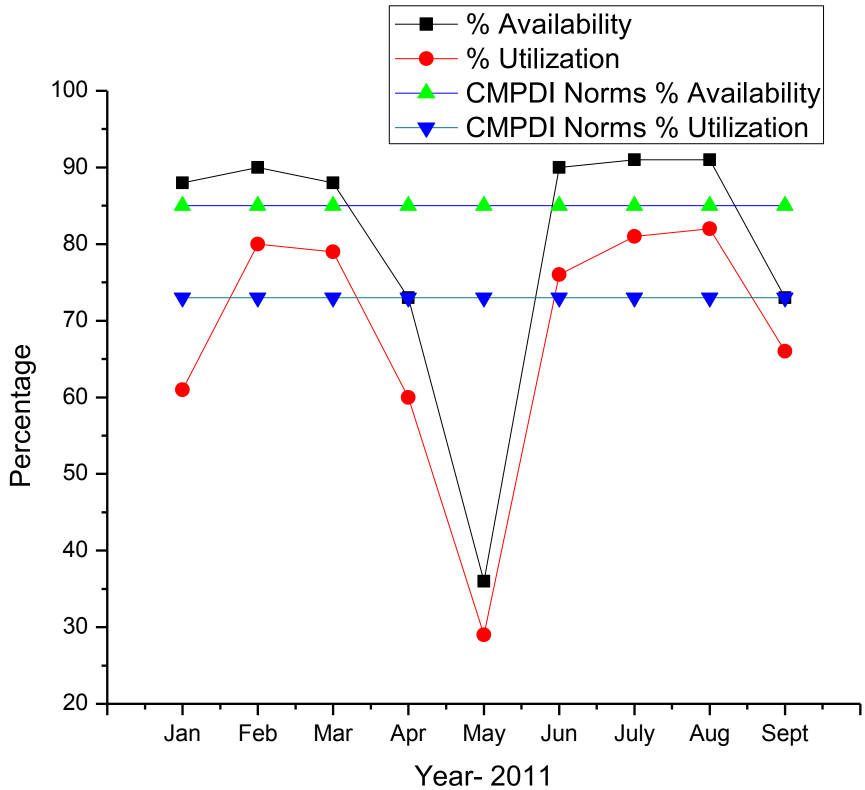


Fig. 3.5: Graph representing percentage Availability and Utilization of Dragline (10/70) for 2011

According to CMPDI norms % Availability and % Utilization of dragline (10/70) is 85 and 73.

As per fig. 3.5 % availability was below as compare with CMPDI norms less in the months: Apr. (73%) May. (36%) and Sept. (73%) because of breakdown and maintenance hours were more in these months. Utilization is less in the months Jan. (61%), Apr. (60%), May. (29%) and Sept. (66%).

Utilization was very poor in May-2011 as compared to other months**.** It was due to non availability of Loose blasted material, power supply and maintenance problem of machine.

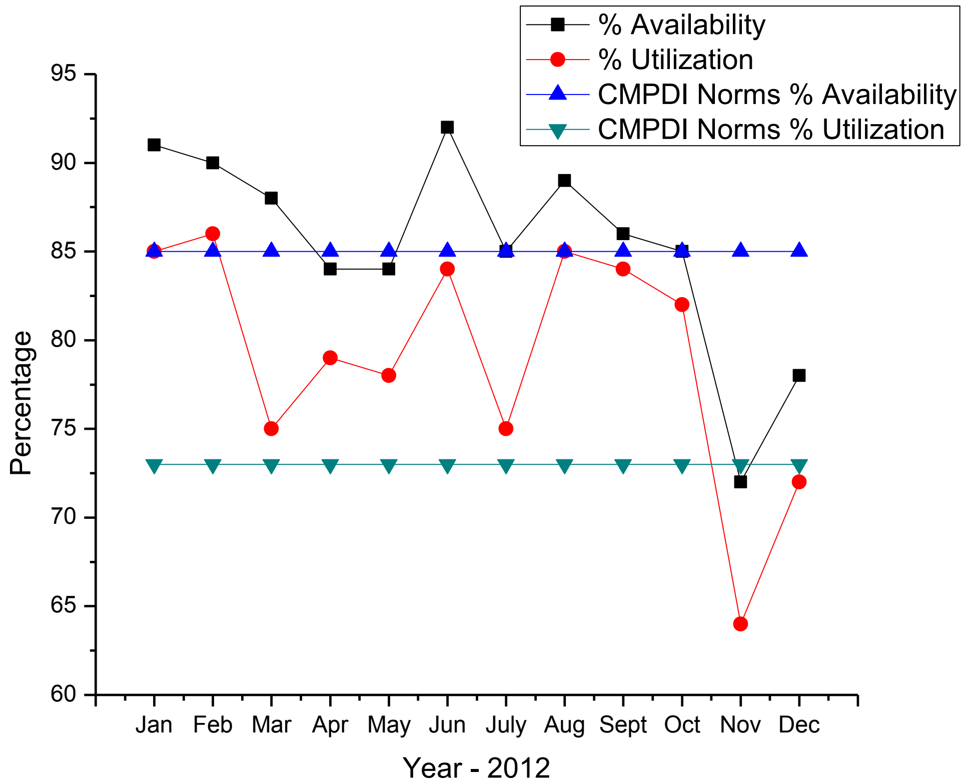


Fig. 3.6: Graph representing percentage Availability and Utilization of Dragline (10/70) for 2012

According to CMPDI norms % Availability and % Utilization of dragline (10/70) is 85 and 73.

As per fig. 3.6 % availability was less in the months Apr (74%) May (74%), Nov (72%) and Dec (78%) as breakdown and maintenance hours were more in these months. Utilization was less in the months Nov (64%) and Dec (72%).

So utilization was less in November because of more idle hours

- No Power supply available all time
- Not used mechanized drill machine
- Dozing operation was not done properly.

3.2.3 COMPARISON OF % AVAILABILITY OF DRAGLINE (10/70) FOR 2010-2012

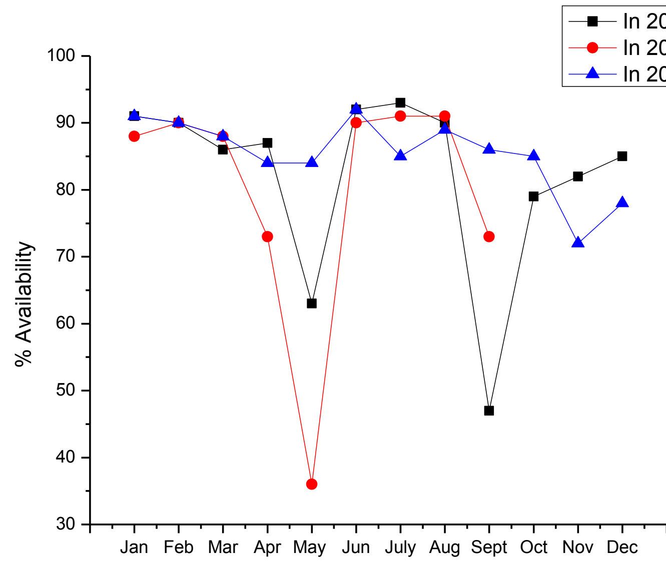


Fig. 3.7: Comparison of availability in Belpahar OCP

3.2.4 COMPARISON OF % UTILIZATION OF DRAGLINE (10/70) FOR 2010-2012

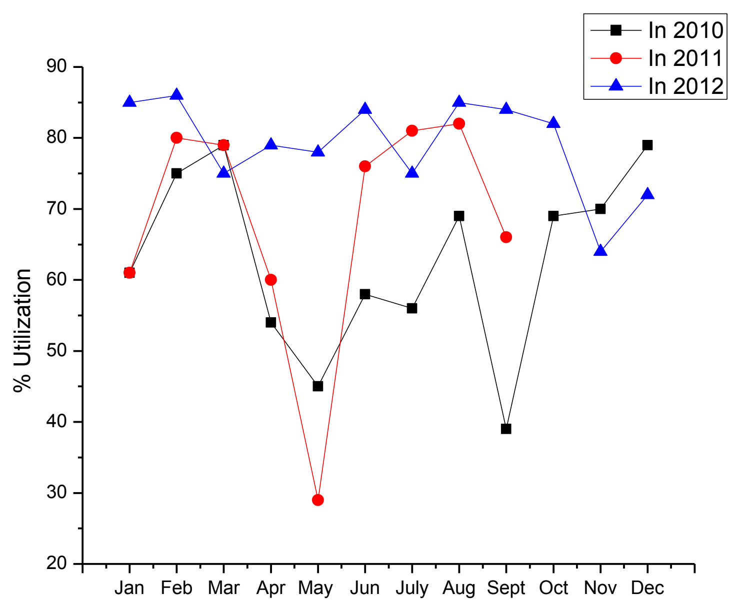


Fig. 3.8: Comparison of utilization in Belpahar OCP

3.2.5 ANALYSIS OF IDLE HOUR OF DRAGLINE (10/70) IN BELPAHAR OCP FOR DECEMBER-2012

Table 3.4: Performance of Dragline for Dec-2012

Dragline(10/70)	Scheduled Shift hour	Working hour	Maintenance hour	Idle hour	Breakdown hour
	650	469	51	41	89

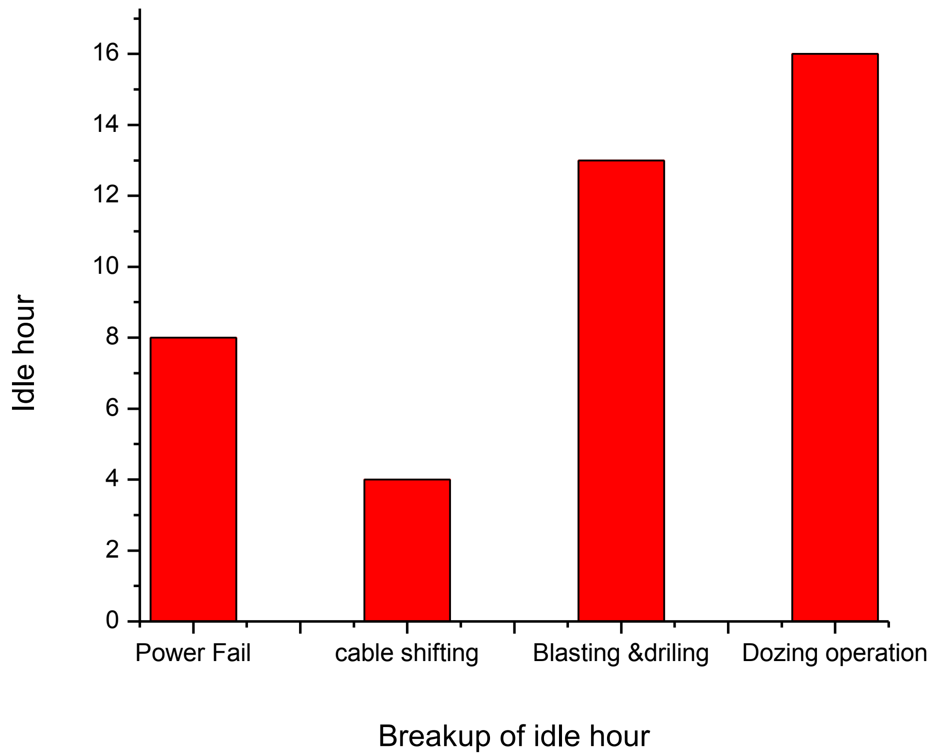


Fig. 3.9: Distribution chart of idle hour for Dec-2012 in Belpahar OCP

As per Table 3.4 doing proper analysis of that dragline (10/70) an investigation was carried out to ascertain the potential areas which lead to the unforeseen idling of that machine. Fig. 3.9 reveals the reasons for loss of available hours due to idle hours. The main reasons were in order: Loss by dozing operation, blasting and drilling, power failure and cable shifting.

3.2.6 OEE CALUCATION OF DRAGLINE (10/70) FOR DECEMBER- 2012 IN BELPAHAR OCP

Table 3.5: Time Lengths of Items for a Dragline (10/70) Operation.

SL.NO.	Item	Time (hours/month)
1	Total time	720 (24 hours/day x 30 days /month)
2	Nonscheduled time	70 (2 days and 10 hrs. off
3	Maintenance time	51
4	Unscheduled maintenance time	89
5	Idle time	41
6	Quality	0.763(Filling Factor)

Availability = {720-70-(51+89)}/720

=0.708

Performance = (510-41)/510

= 0.919

OEE=Availability x Performance x Quality

=0.708x0.919x0.763

=0.496 (50%)

3.2.7 OEE CALCULATION OF SURFACE MINER FOR DEC-2012 IN BELPAHAR OPENCAST MINE

Table 3.6: During the Surface Miner operation the following time losses are occurred:

	Item	**Time (hours/month)**
1	Total time	720 (24 hours/day x 30 days /month)
2	Nonscheduled time	70 (2 days and 10 hrs. off
3	Maintenance time	40
4	Unscheduled maintenance time	9
5	Idle time	132
6	Quality	0.733(Filling Factor)

Availability = {720-70-(40+9)}/720

=0.834

Performance = (601-132)/601

= 0.780

OEE=Availability x Performance x Quality

=0.834x0.780x0.86

=0.552(55%)

3.3 MONTHLY PERFORMANCE OF DRAGLINE (10/70) AT SAMELESWARI OCP

Table 3.7 Performance of Dragline (10/70) at Sameleswari OCP for 2010

Sl. No.	Sheduled Shift hrs.	Working hours	Breakdown hours	idle hours	Maintenance hours	%Availability	%Utilization
JANUARY	670	327	234	88	25	61	52
FEBRUARY	670	593	15	29	39	92	88
MARCH	630	464	100	46	20	81	73
APRIL	670	586	26	25	38	90	87
MAY	650	545	27	35	43	89	84
JUNE	670	485	65	83	33	85	72
JULY	650	410	132	86	22	76	63
AUGUST	670	525	20	87	38	91	78
SEPTEMBER	670	287	301	68	19	52	43
OCTOBER	650	378	108	139	29	78	58
NOVEMBER	670	541	20	67	42	90	80
DECEMBER	650	528	18	68	36	91	81

Table 3.8: Performance of Dragline (10/70) at Sameleswari OCP for 2011

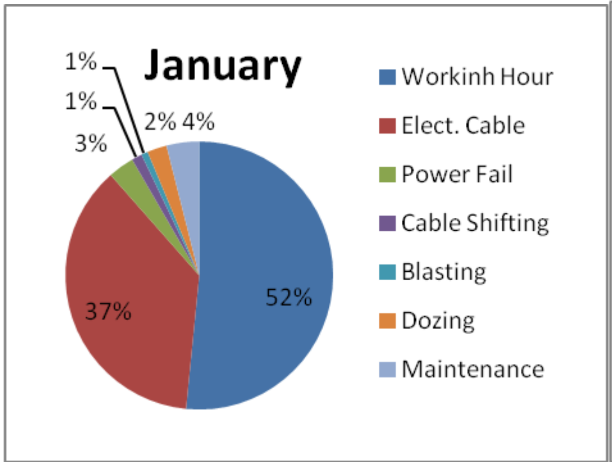
Sl. No.	Sheduled Shift hrs.	Working hours	Breakdown hours	idle hours	Maintenance hours	%Availability	%Utilization
JANUARY	670	327	234	83	25	62	49
FEBRUARY	670	593	15	23	39	91	88
MARCH	630	464	100	46	20	80	73
APRIL	670	586	26	20	38	90	87
MAY	650	545	27	35	43	89	83
JUNE	670	485	65	83	33	85	72
JULY	650	410	132	86	22	76	63
AUGUST	670	525	20	87	38	91	78
SEPTEMBER	670	357	210	63	40	59	53
OCTOBER	650	378	108	135	29	79	58
NOVEMBER	670	531	20	67	52	89	79
DECEMBER	650	508	28	69	46	88	78

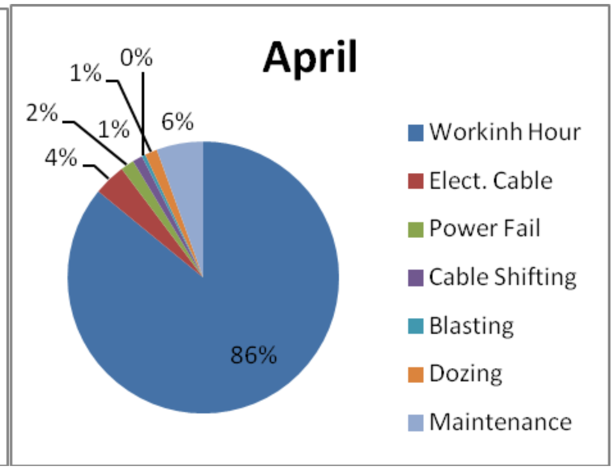
Table 3.9: Performance of Dragline (10/70) at Sameleswari OCP for 2012

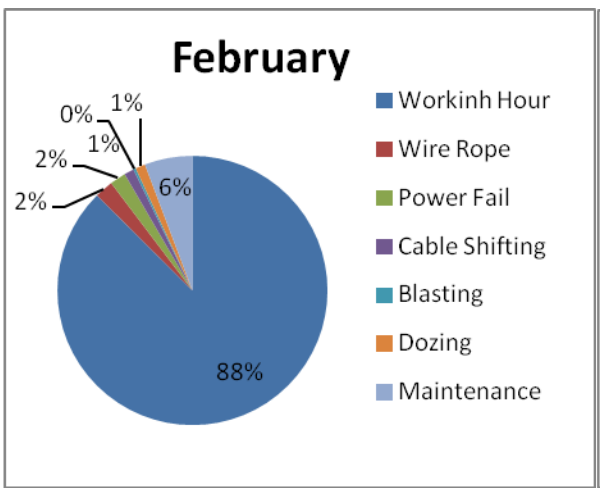
Sl. No.	Sheduled Shift hrs.	Working hours	Breakdown hours	idle hours	Maintenance hours	%Availability	%Utilization
JANUARY	670	398	103	131	38	79	59
FEBRUARY	670	493	32	56	49	87	79
MARCH	630	538	47	30	55	83	78
APRIL	670	586	26	20	38	90	87
MAY	650	545	27	35	43	89	83
JUNE	670	508	25	97	40	90	75
JULY	650	527	18	58	38	91	82
AUGUST	670	352	150	142	26	73	53
SEPTEMBER	670	61	582	4	3	13	12
OCTOBER	650	150	496	10	14	21	20
NOVEMBER	670	535	35	43	37	89	82
DECEMBER	650	396	120	110	34	74	58

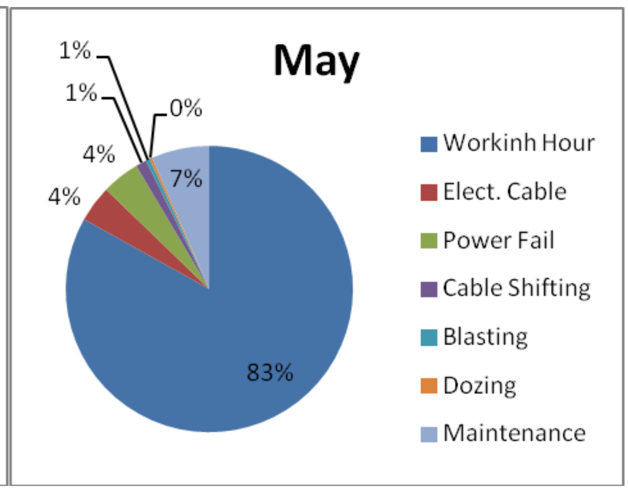
3.3.1 Pie charts on monthly performance assessment of Dragline (10/70) at Sameleswari OCP for the years 2010-12 have been presented in Figs. 3.11 to 3.13

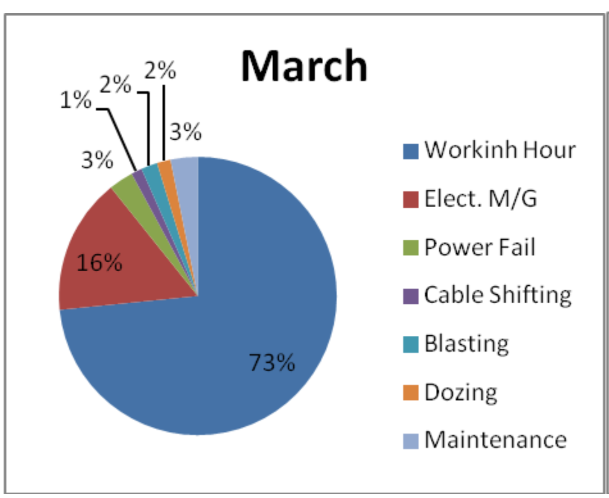
FOR 2010

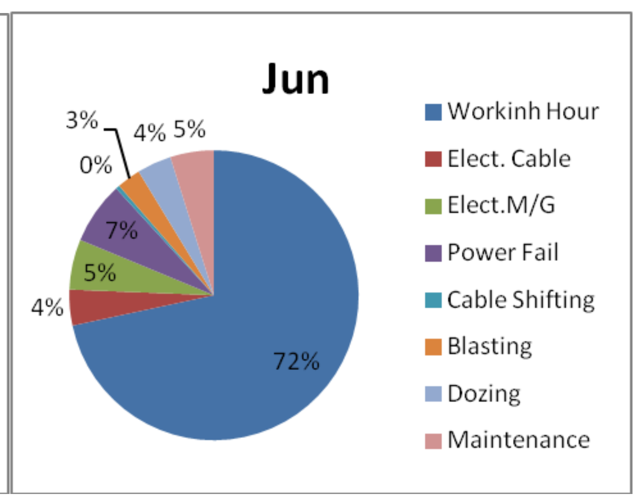


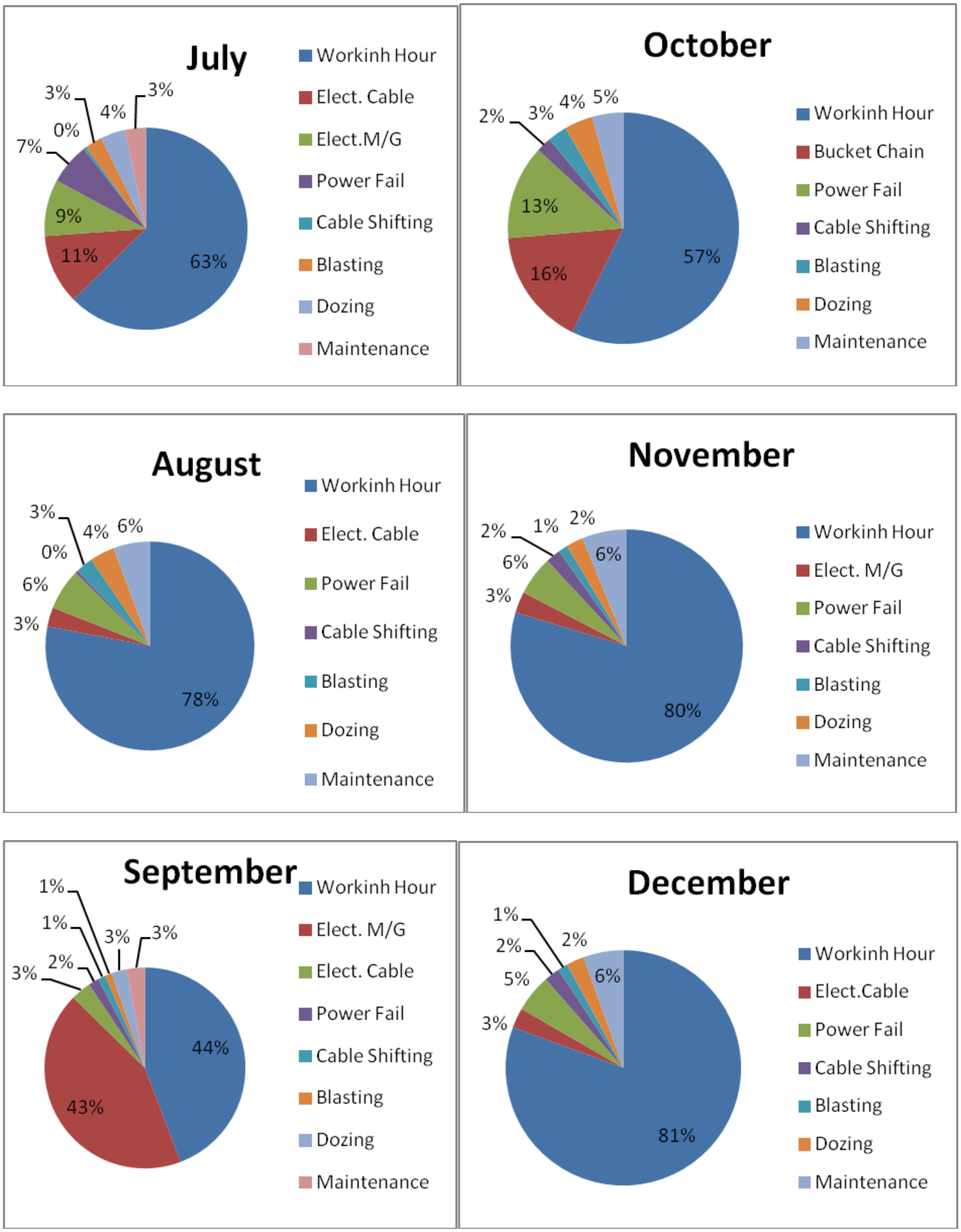






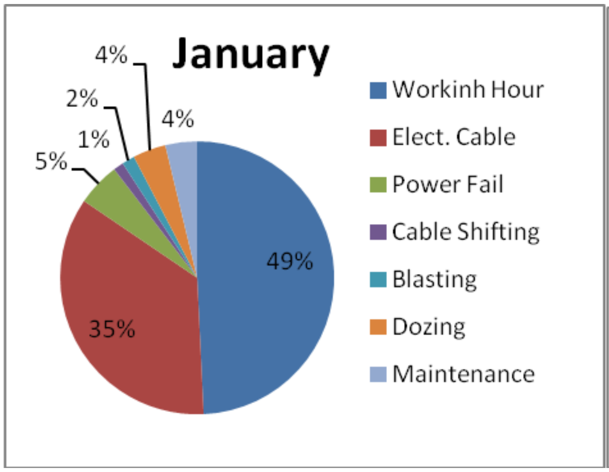


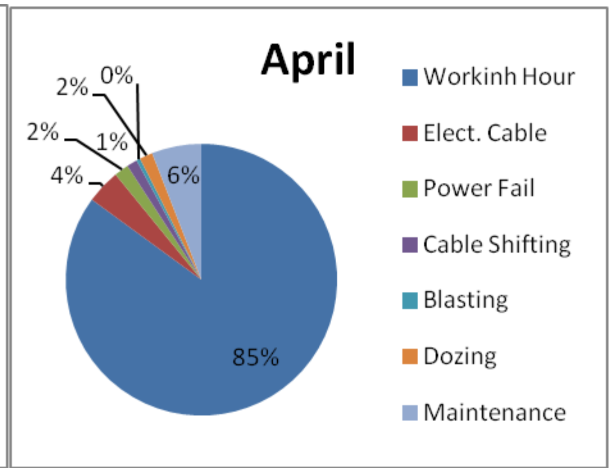


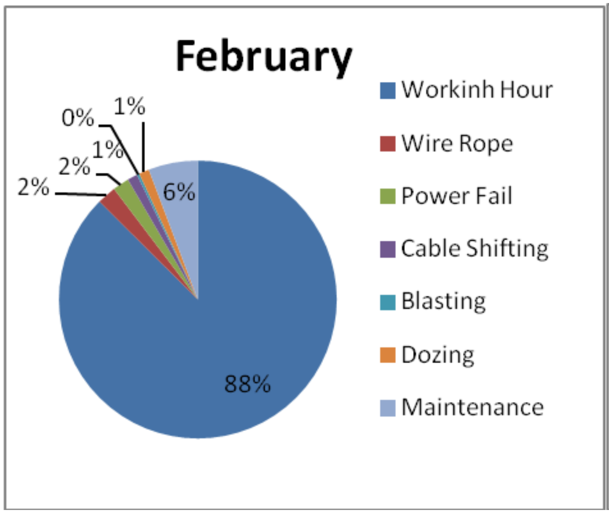


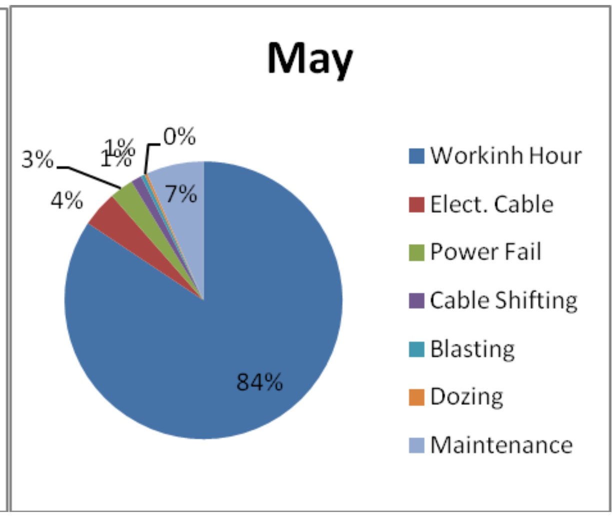
Figs. 3.10 Pie charts for Dragline (10/70) at SOCP in 2010

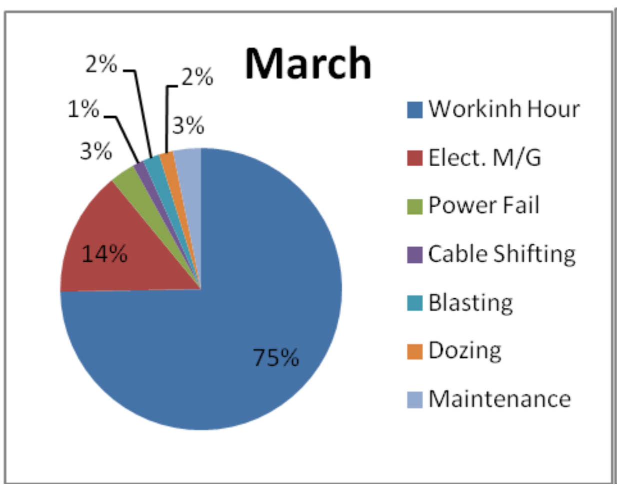
FOR 2011

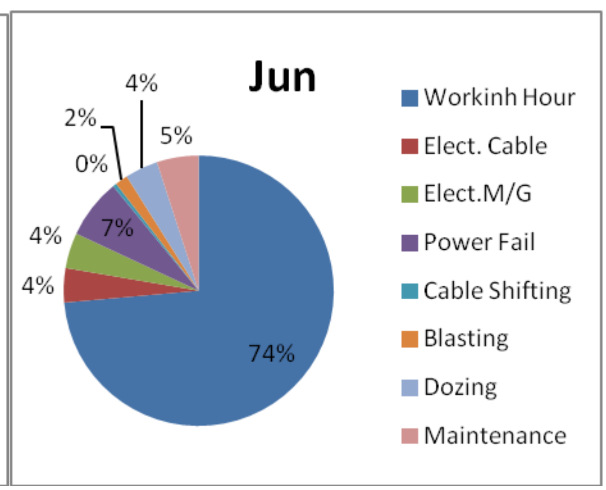

January
4%
2%
4%
1%
5%
49%
35%
Workinh Hour
Elect. Cable
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance

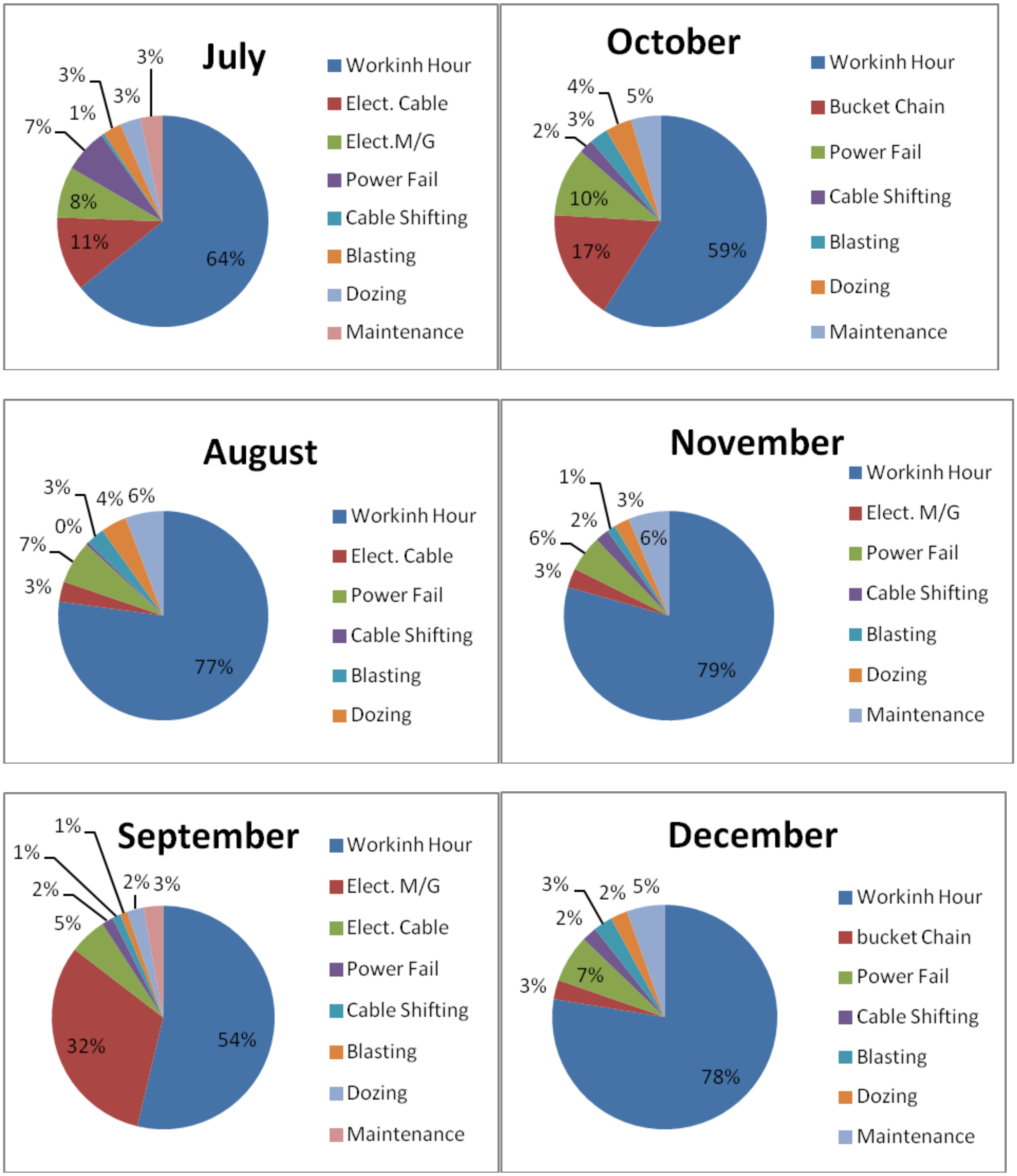

April
2%
0%
2%
1%
4%
6%
85%
Workinh Hour
Elect. Cable
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


February
0%
1%
1%
2%
2%
6%
88%
Workinh Hour
Wire Rope
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


May
3%
1%
0%
4%
7%
84%
Workinh Hour
Elect. Cable
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance

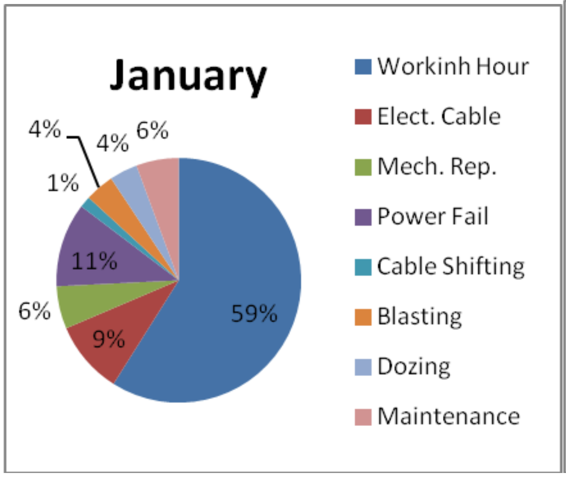

March
2%
2%
1%
3%
3%
14%
75%
Workinh Hour
Elect. M/G
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance

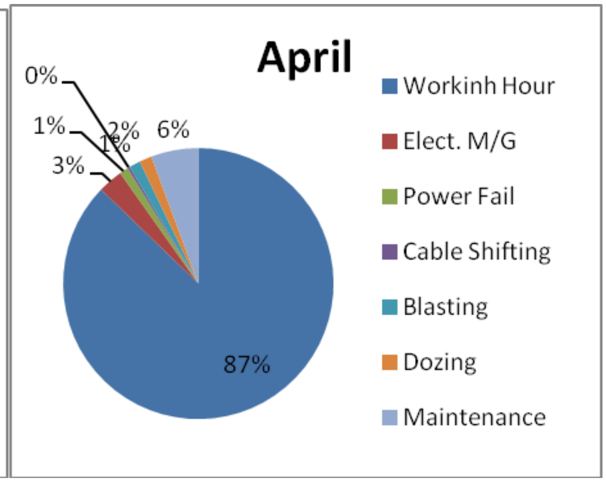

Jun
4%
2%
5%
0%
7%
4%
4%
74%
Workinh Hour
Elect. Cable
Elect.M/G
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance

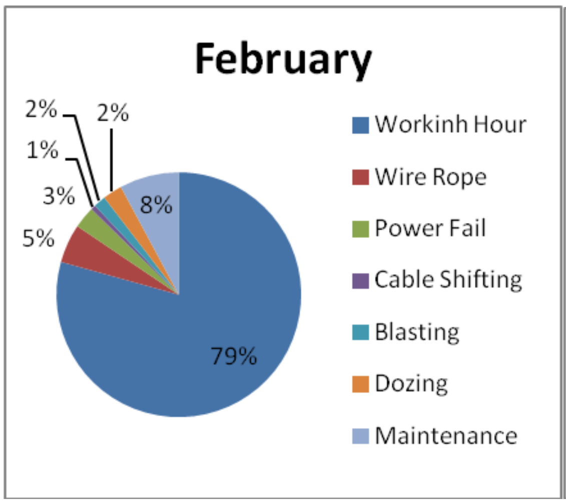


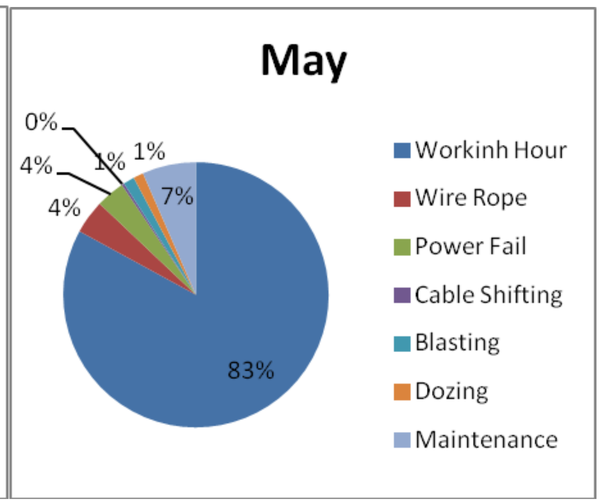
Figs. 3.11 Pie charts for Dragline (10/70) at SOCP in 2011

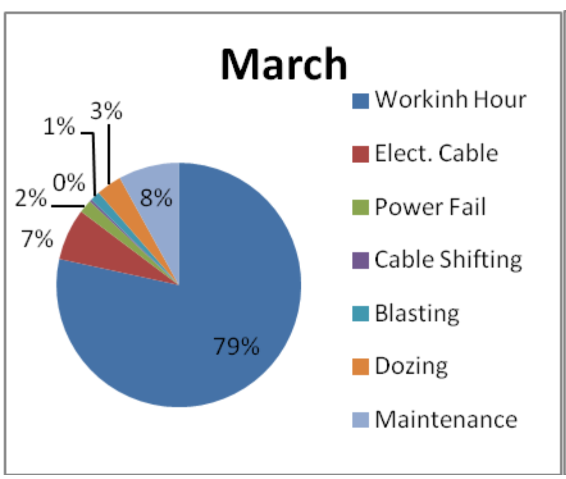
FOR 2012

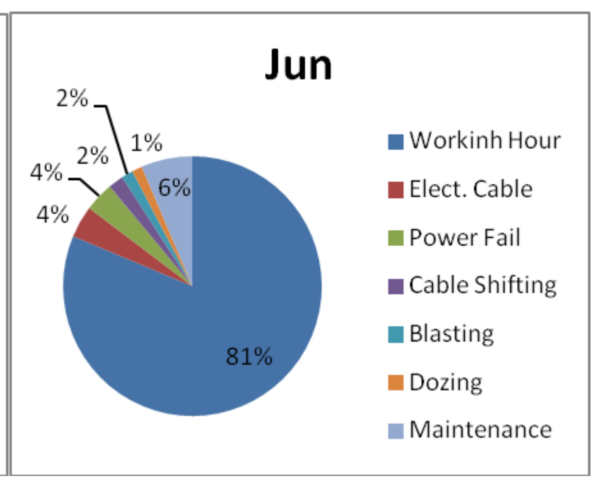

January
4%
4%
6%
1%
11%
6%
9%
59%
Workinh Hour
Elect. Cable
Mech. Rep.
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance

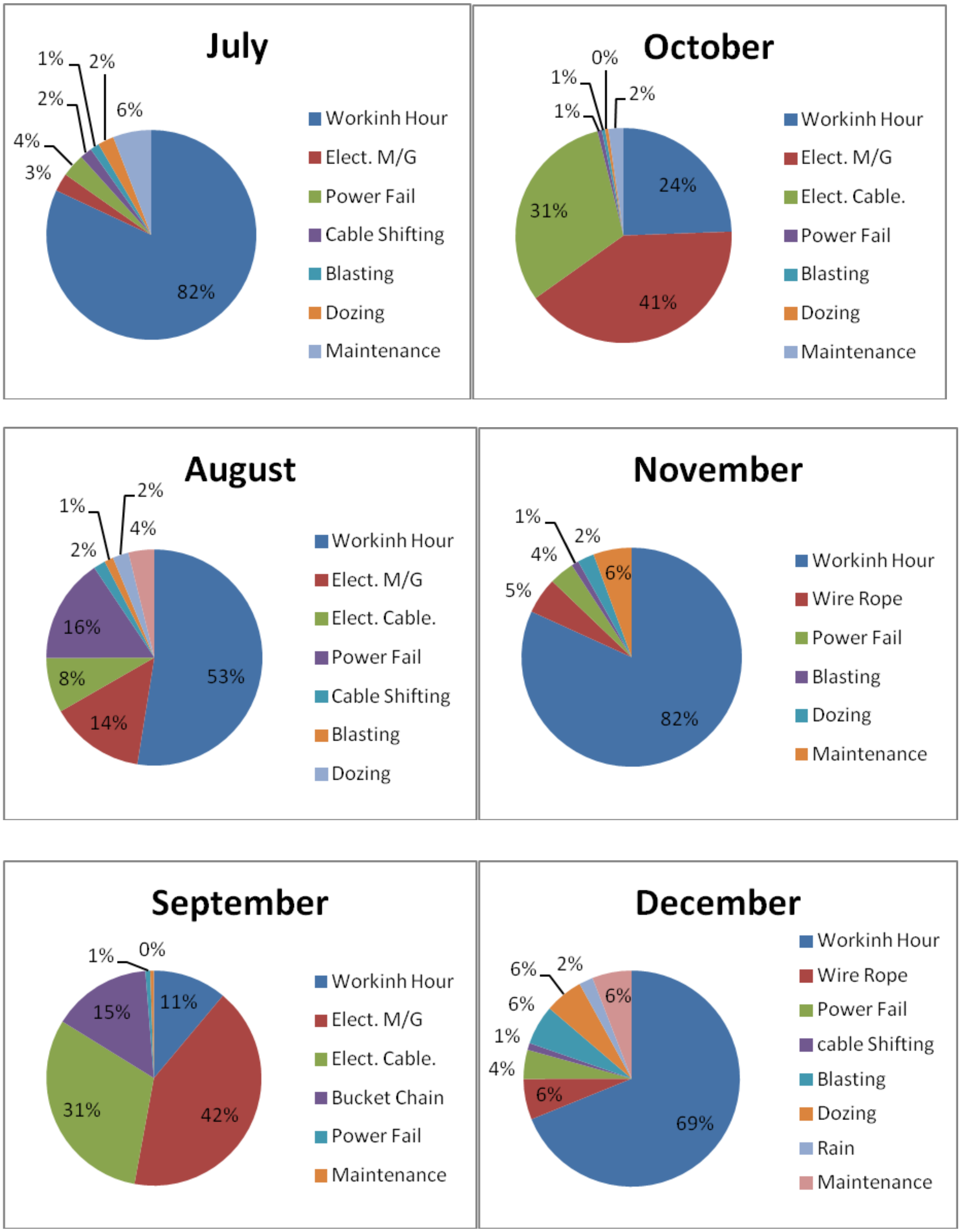

April
0%
1%
2%
1%
6%
3%
87%
Workinh Hour
Elect. M/G
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


February
2%
2%
1%
3%
8%
5%
79%
Workinh Hour
Wire Rope
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


May
0%
4%
1%
1%
4%
7%
83%
Workinh Hour
Wire Rope
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


March
1%
3%
2%
0%
8%
7%
79%
Workinh Hour
Elect. Cable
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance


Jun
2%
2%
1%
4%
6%
4%
81%
Workinh Hour
Elect. Cable
Power Fail
Cable Shifting
Blasting
Dozing
Maintenance



Figs. 3.12 Pie charts for Dragline (10/70) at SOCP in 2012

3.3.2 %AVAILABILITY AND %UTILIZATION GRAPH OF DRAGLINE (10/70) FOR SAMELESWARI OCP

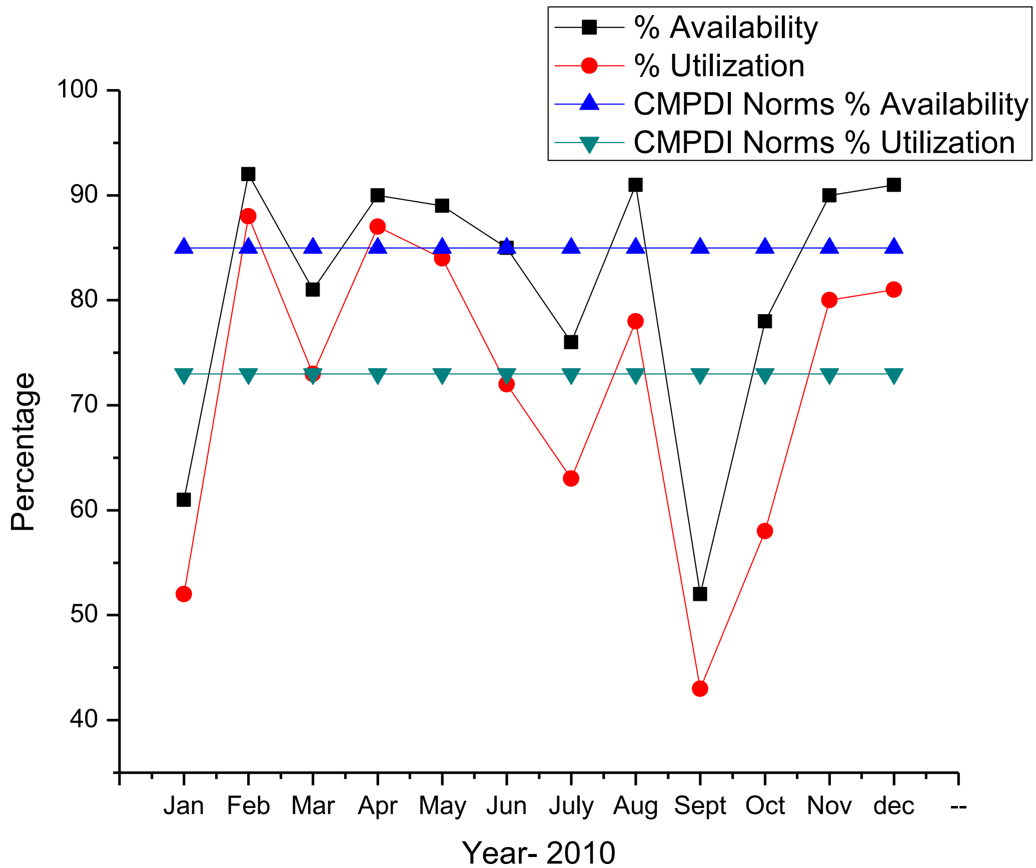


Fig. 3.13: Graph representing percentage Availability and Utilization of Dragline (10/70) for 2010

According to CMPDI norms % Availability and % Utilization of Dragline (10/70) is 85% and 73%. As per fig 3.13 availability (52%) and Utilization (43%) of Dragline was poor in Sept. – 2010. It was due to more breakdown hours caused by machine repairing work

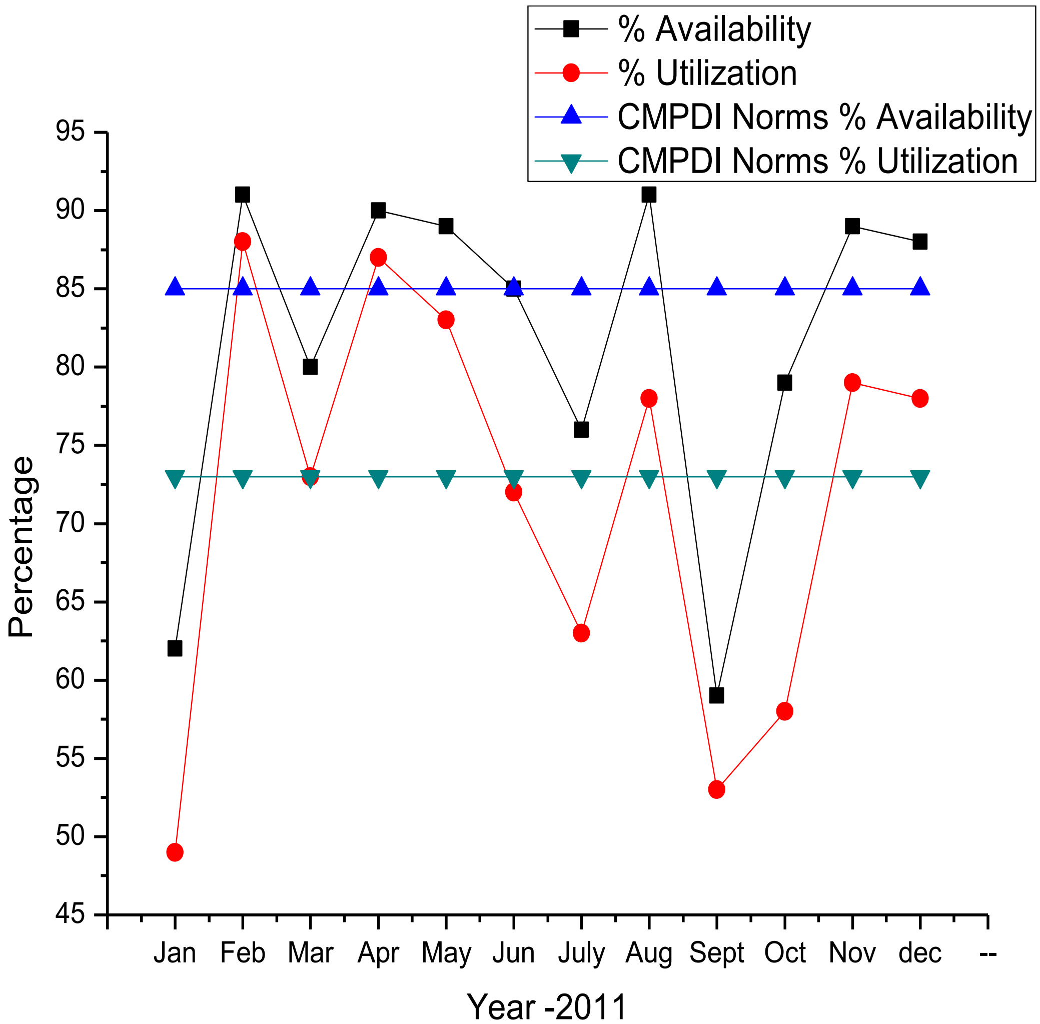


Fig. 3.14: Graph representing percentage Availability and Utilization of Dragline for 2011

According to CMPDI norms % Availability and % Utilization of dragline (10/70) is 85% and 73%.

As per fig. 3.14 it was observed that lowest availability (62%) and utilization (49%) of dragline was in Jan. - 2011 as compared to other months. It was due to face not sufficient loose blasted material, availability of power supply was not all time and no proper preventive maintenance of machine.

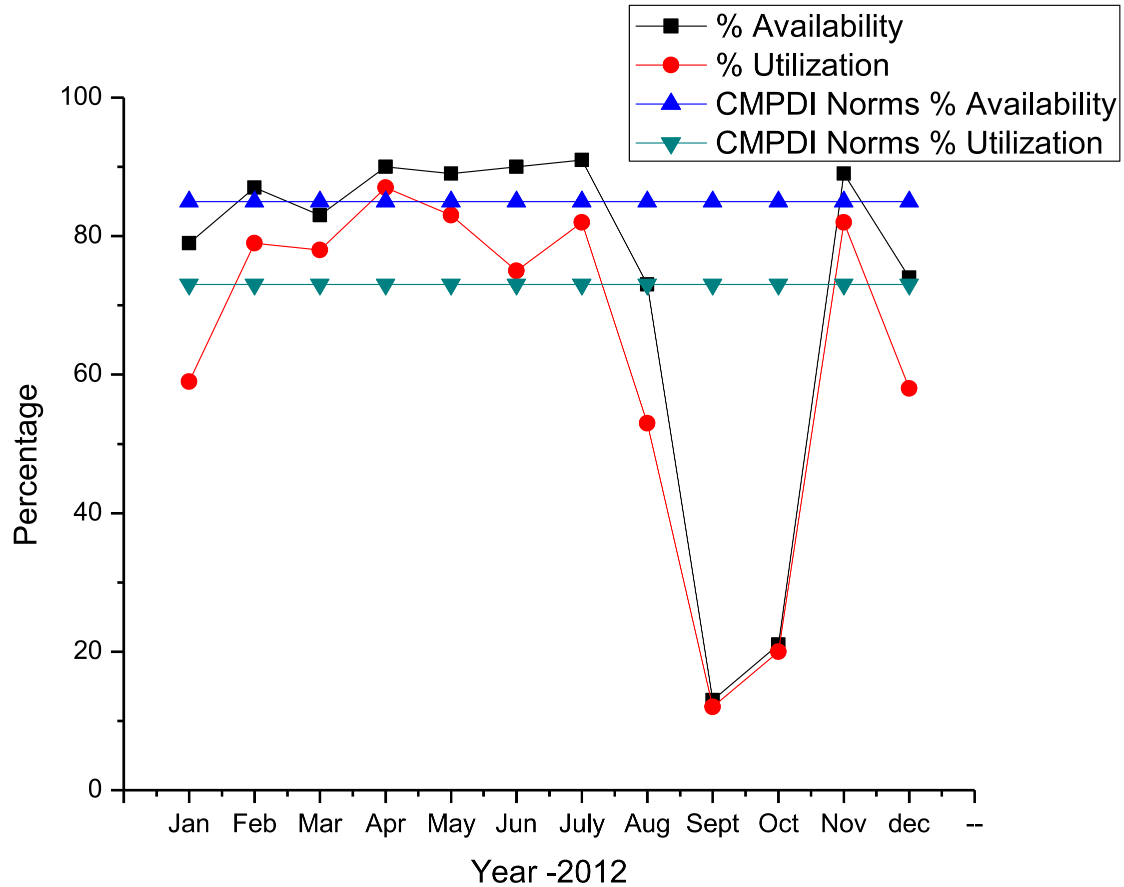


Fig. 3.15: Graph representing percentage Availability and Utilization of Dragline (10/70) for 2012

According to CMPDI norms % Availability and % Utilization of dragline (10/70) is 85 and 73.

As per fig.3.15 Availability (13%) was very poor in Sept. -2012 as compared to other months.

Because breakdown and maintenance hours were much more.

So utilization (12%) was very less because of more idle hours (No Power supply available all time, not used mechanized drill machine, Dozing operation was not done proper)

3.3.3 COMPARISON OF % AVAILABILITY OF DRAGLINE (10/70) FOR 2010-2012

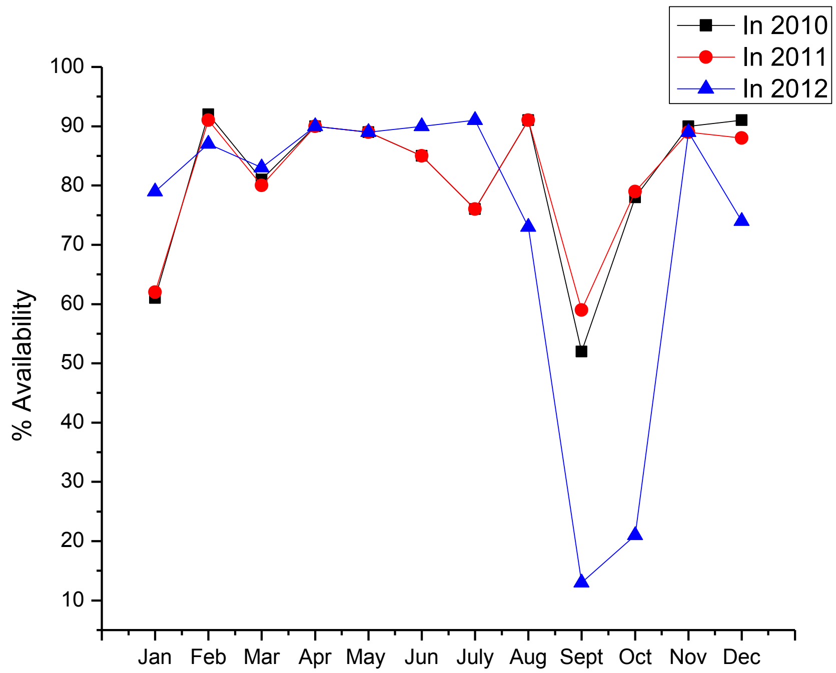


Fig. 3.16: Comparison of availability in Sameleswari OCP

3.3.4 COMPARISON OF % UTILIZATION OF DRAGLINE (10/70) FOR 2010-2012

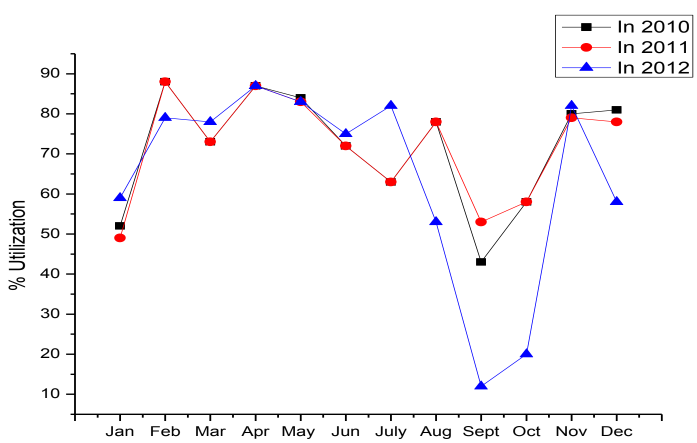


Fig 3.17: comparison of %utilization in Sameleswari OCP

3.3.5 ANALYSIS OF IDLE HOUR OF DRAGLINE (10/70) IN SAMLESWARI OCP FOR DECEMBER-2012

Table 3.10: Performance of Dragline for Dec-2012 in Sameleswari OCP

Dragline(10/70)	Scheduled Shift hour	Working hour	Maintenance hour	Idle hour	Breakdown hour
	650	396	34	110	130

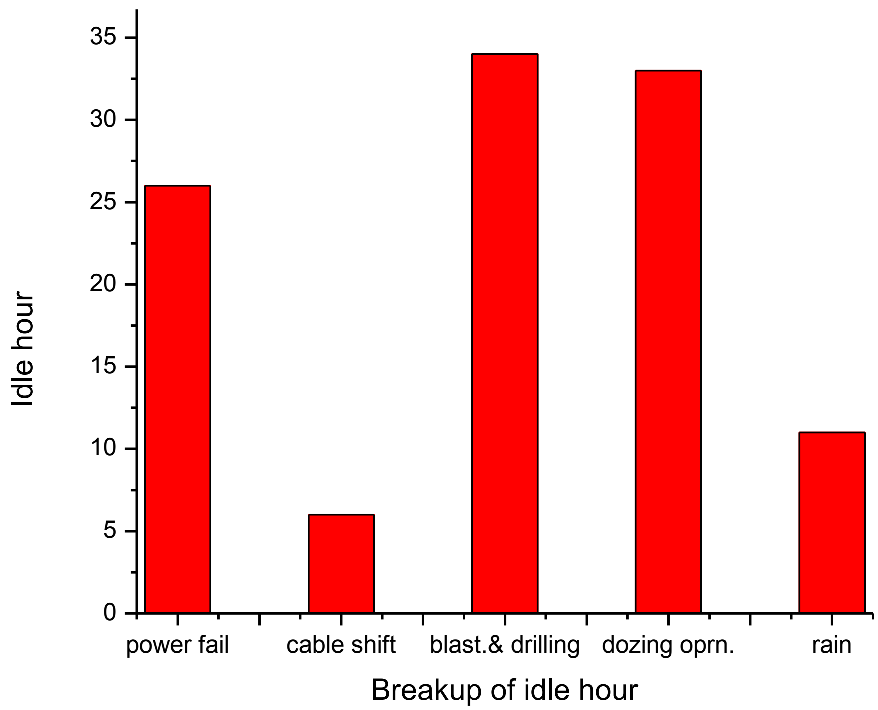


Fig 3.18: Distribution chart of idle time for dec-2012 in Sameleswari OCP

As per Table 3.10 doing proper analysis of that dragline (10/70) an investigation was carried out to ascertain the potential areas which lead to the unforeseen idling of that machine. Fig. 3.18 reveals the reasons for loss of available hours due to idle hours. The main reasons were in order: Loss by Blasting and drilling, dozing operation, Power fail, rain, and cable shifting.

3.3.6 OEE CALUCATION OF DRAGLINE (10/70) FOR DECEMBER- 2012 IN SAMELESWARI OCP

Table 3.11: Time Lengths of Items for a Dragline (10/70) Operation.

	Item	**Time (hours/month)**
1	Total time	720 (24 hours/day x 30 days /month)
2	Nonscheduled time	70 (2 days and 10 hrs. off
3	Maintenance time	34
4	Unscheduled maintenance time	130
5	Idle time	110
6	Quality	0.733(Filling Factor)

Availability = {720-70-(34+130)}/720

=0.675

Performance = (396-110)/396

= 0.772

OEE=Availability x Performance x Quality

=0.675x0.772x0.733

=0.38 (38%)

3.3.7 OEE CALCULATION OF SURFACE MINER FOR DEC-2012 IN SAMELESWARI OCP

Table 3.12: During the surface miner operation the following time losses are occurred:

	Item	**Time (hours/month)**
1	Total time	720 (24 hours/day x 30 days /month)
2	Nonscheduled time	70 (2 days and 10 hrs. off
3	Maintenance time	60.5
4	Unscheduled maintenance time	10
5	Idle time	213.5
6	Quality	0.86 (Filling Factor)

Availability = {720-70-(60.5+10)}/720

=0.80

Performance = (579-213.5)/579

= 0.63

OEE=Availability x Performance x Quality

=0.80x0.63x0.86

=0.43 (43%)

3.4 Comparative assessment performance of Dragline (10/70) at BOCP during 2010 – 2012

For %Availability

Table 3.13: Comparative %availability of Dragline (10/70) at BOCP during 2010-2012

Year	Months below norms	Max.	Min.	CMPDI Norms	Remarks
2010	May, Sept, Nov	91%	47%	85%	Average %Availability of Dragline in 2012 was found to be more as compared the other years and May-2011 is very poor. Average % availability during 2010-2012 was found to be 80.71%
2011	Apr, May, Sept	91	36		
2012	May, Nov, Dec	91	73		

For %Utilization

Table 3.14: Comparative %utilization of Dragline (10/70) at BOCP during 2010-2012

Year	Months below norms	Max.	Min.	CMPDI Norms	Remarks
.2010	Jan, Apr, May, Jun, Jul, Aug, Sept, Oct, Nov.	79%	39	73%	Average %Utilization of Dragline in 2012 was found to be more as compare of other years and sept-2011and may-2012 was found to be very poor. Average %utilization during 2010-2012 was found to be 66.79%.
2011	Jan, Apr, May, Sept	82%	29%		
2012	Nov, Dec	86%	64%		

3.5 Comparative assessment performance of Dragline (10/70) at SOCP during 2010 – 2012

For Dragline (10/70)

Table 3.15: Comparative %availability of Dragline (10/70) at SOCP during 2010-2012

Year	Months below norms	Max.	Min.	CMPDI Norms	Remarks
2010	Jan, Mar, Jul, Sept, Oct	92%	52%	85%	Average %Availability of Dragline in 2011 is more as compare of other years. And sept-2012 was found to be very poor. Average %availability during 2010-2012 was found to be 78.72%
2011	Jan, Mar, Jul, Sept, Oct	91%	62%		
2012	Jan, Aug, Sept, Oct,, Dec	91%	13%		

For %Utilization

Table 3.16: Comparative %utilization of Dragline (10/70) at SOCP during 2010-2012

Year	Months below norms	Max.	Min.	CMPDI Norms	Remarks
2010	Jan, Jun, Jul, Sept, Oct,	88%	43%	73%	Average %Utilization of Dragline in 2011 is more as compare of other years and Sept-2012 was found to be very poor. Average % utilization during 2010-2012 was found to be 69.03%
2011	Jan, Jun, Jul, Sept, Oct,	88%	49%		
2012	Jan, Sept, Oct, Dec	75%	12%		

3.6 Comparative OEE of Dragline (10/70) at BOCP and SOCP

For Dragline (10/70)

Table 3.17: Comparative OEE of Dragline (10/70) at BOCP and SOCP

	BOCP	SOCP	Remarks
Availability	0.78	0.675	OEE of Dragline (10/70)at BOCP is found be better than at SOCP
Performance	0.91	0.772	
Quality	0.763	0.733	
OEE	50%	38%	

For Surface Miner

Table 3.18: Comparative OEE of Surface Miner Wirtgen-2200 at BOCP and SOCP

	BOCP	SOCP	Remarks
Availability	0.83	0.80	OEE of Surface Miner at BOCP is found be better than at SOCP
Performance	0.78	0.63	
Quality	0.86	0.86	
OEE	55%	43%	

CHAPTER 4

CONCLUSIONS AND REFERENCES

CONCLUSIONS

Based on the field studies and analysis of data of Availability and Utilization of Draglines and Surface Miner at Belpahar and Sameleswari OCP the following conclusions are made:

- For Belpahar OCP, the average% availability and % utilization of Dragline (10/70) were found to be 80.71% and 66.79% respectively.
- For Sameleswari OCP the average % availability and % utilization of Dragline (10/70) were found to be 78.72% and 69.03% respectively.
- For Belpahar OCP, OEE of Dragline (10/70) was found to be 50%. For Sameleswari OCP, OEE of dragline (10/70) was found to be 38%. Hence OEE of Dragline (10/70) at BOCP was found be better than at SOCP.
- For Belpahar OCP, OEE of Surface Miner Wirtgen-2200 was found to be 55%. For Samleswari OCP, OEE of Surface Miner Wirtgen-2200 was found to be 43%. Hence the OEE of Surface Miner Wirtgen-2200 at BOCP was found be better than that at SOCP.

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